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Risø Report No. 291

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Danish Atomic Energy Commission

Research Establishment Risø

Environmental Radioactivity in Denmark in 1972

by A. Aarkrog and J. Lippert

June 1973

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Environmental Radioactivity in Denmark in 1972

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A. Aarkrog and J. Lippert

Danish Atomic Energy Commission
Research Establishment Risø
Health Physics Department

UDC 614.73 (489)

Abstract

The present report deals with the measurement of fall-out radioactivity in Denmark in 1972. Strontium-90 was determined in samples from all over the country of precipitation, soil, ground water, sea water, grass, dried milk, fresh milk, grain, bread, potatoes, vegetables, fruit, total diet, drinking water, and human bone. Furthermore ^{90}Sr was determined in local samples of air, rain water, grass, sea plants, fish, and meat. Caesium-137 was determined in soil, sea water, milk, grain products, potatoes, vegetables, fruit, total diet, and meat, and ^{137}Cs was measured by wholebody counting in persons from a control group at Risø. Estimates of the mean contents of radiostrontium and radiocaesium in the human diet in Denmark in 1972 are given. The γ-background was measured regularly at locations around Risø, at ten of the State experimental farms and in an area in Zealand, one in Jutland where future nuclear power plants might be located, and along the shores of the Great Belt. Finally the report includes, as previously, regular surveys of environmental samples from the Risø area.

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ABBREVIATIONS AND UNITS

FP	Fission products
pCi	picocurie, 10^{-12} Ci, μμCi
nCi	nanocurie, 10^{-9} Ci, mμCi
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
c/min	counts per minute
d/min	disintegrations per minute
c/h	counts per hour
μR	micro-roentgen, 10^{-6} roentgen
S. U.	pCi ^{90}Sr/g Ca
O. R.	observed ratio
M. U.	pCi ^{137}Cs/g K
V	vertebrae
m	male
f	female
n Sr	natural (stable) Sr
eqv. μg U	equivalents μg uranium: activity as from 1 μg U (~90 d/h)
eqv. mg KCl	equivalents mg KCl: activity as from 1 mg KCl (~0.88 d/min)
S. D.	standard deviation: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{(n-1)}}$
S. E.	standard error: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{n(n-1)}}$
U. C. L.	upper control level
L. C. L.	lower control level
Δ	one standard deviation due to counting
S. S. D.	sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$
f	degrees of freedom
s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	probability fractile of the distribution in question
η	coefficient of variation, relative standard deviation
anova	analysis of variance

Samples:

H:	sea water
J:	soil
L:	air
B:	bed soil
Å:	eel
PG:	grass
PH:	sea plants
D:	drain water
S:	waste water
R:	precipitation
M:	milk

1. INTRODUCTION

1.1.

The present report is the sixteenth of a series of periodical reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark.

The programme is nearly unchanged as compared with 1971. No samples of fresh water were collected from Danish streams and lakes in 1972.

1.2.

The methods of radiochemical analysis[2-4] and the statistical treatment of the results[5] are still based on the principles established in previous reports[1].

1.3.

The report does not include detailed tables of the total β-measurements from the environmental control of the Risø site. These tables are available in the form of microcards at the library of the Danish Atomic Energy Commission at Risø.

1.4.

The report contains no information as regards sample collection and analysis except in the cases where these procedures have been altered.

1.5.

In 1972 the personnel of the Environmental Control Section of the Health Physics Department consisted of one chemist, ten laboratory technicians, two sample collecters, and two dishwashers. As in previous years, important assistance was rendered by the Section for Electronics Development, not only in the maintenance of the counting equipment, but also in the interpretation of the γ-spectra. The computer program (cf. 2) used in the calculations of ^{90}Sr as well as in the γ-analysis were developed by the Section for Electronics Development.

1.6.

The composition of the Danish average diet used in this report is identical with that proposed in 1962 by the nutritional consultant to the Atomic Energy Commission, Professor E. Hoff-Jørgensen, Ph. D.

2. ORGANIZATION AND FACILITIES[1, 6, 7, 8)]

We have now 3 Ge(Li)-detectors each connected to a 1024-channel analyzer. One of the analyzers is also used for the wholebody countings with the 8 inch NaI crystal. The output from the 3 analyzers are fed to a 9810A HP-calculator.

3. RISØ ENVIRONMENTAL MONITORING IN 1972

3.1. Gross β-Activity

3.1.1. Sea Water

Fig. 3.1.1.1 shows the sample locations in Roskilde Fjord. Fig. 3.1.1.2 shows the control chart for H I. The yearly mean for H I in 1972 was 56 eqv. mg KCl/2.5 g (in 1971: 57), for H III-VI: 58 eqv. mg KCl/2.5 (in 1971: 59) and for H VII-X: 56 eqv. mg KCl/2.5 g (in 1971: 59). Fig. 3.1.1.3 shows the mean levels of radioactivity in sea salt since 1957.

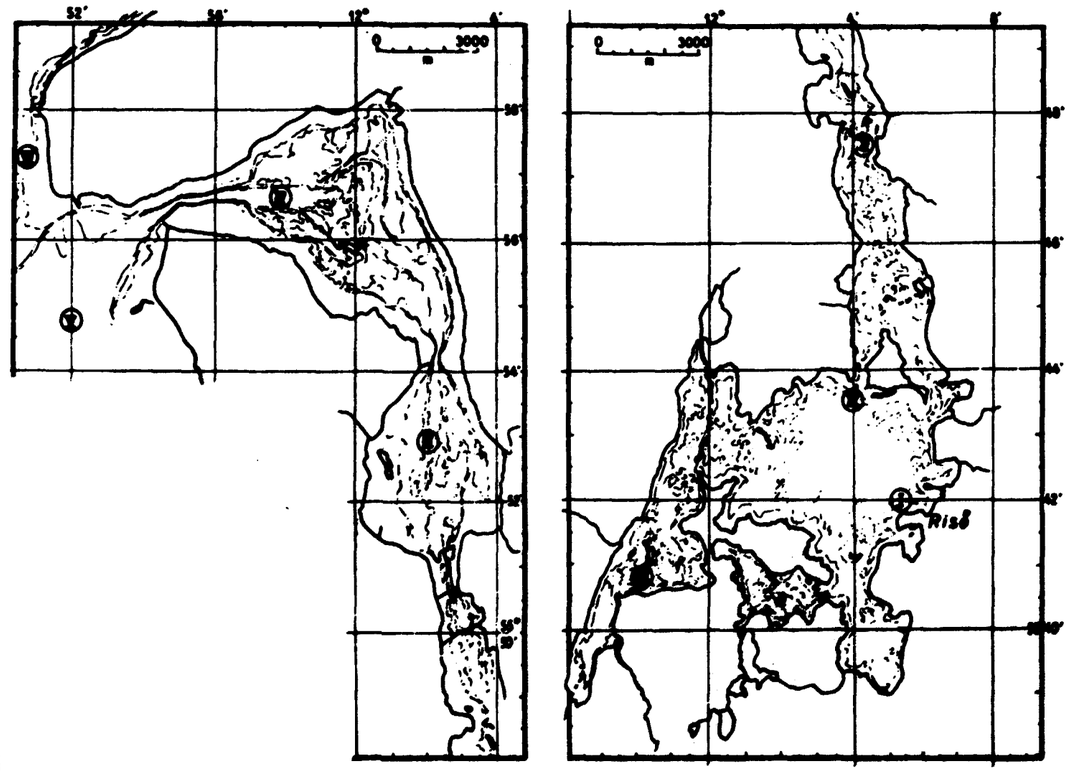

Fig. 3.1.1.1. Roskilde Fjord.

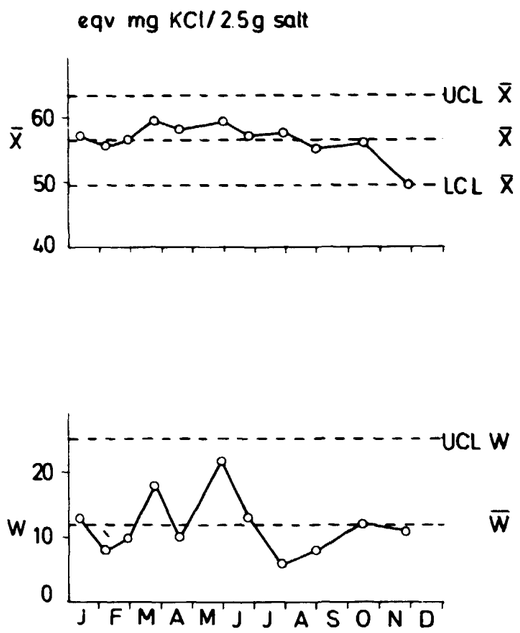

Fig. 3.1.1.2. Control chart for HI, 1972.

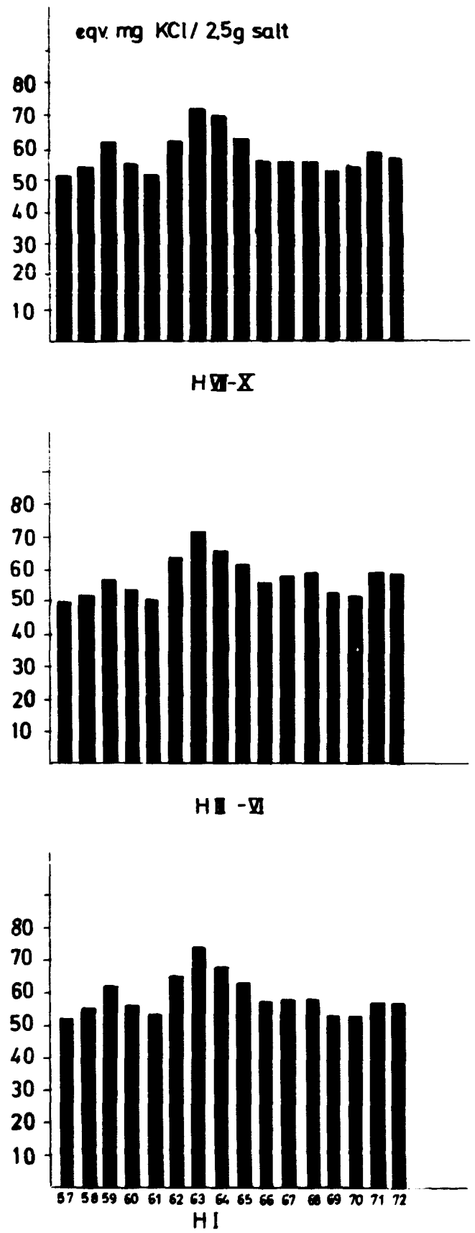

Fig. 3.1.1.3.
Mean radioactivity in sea water, 1957-72.

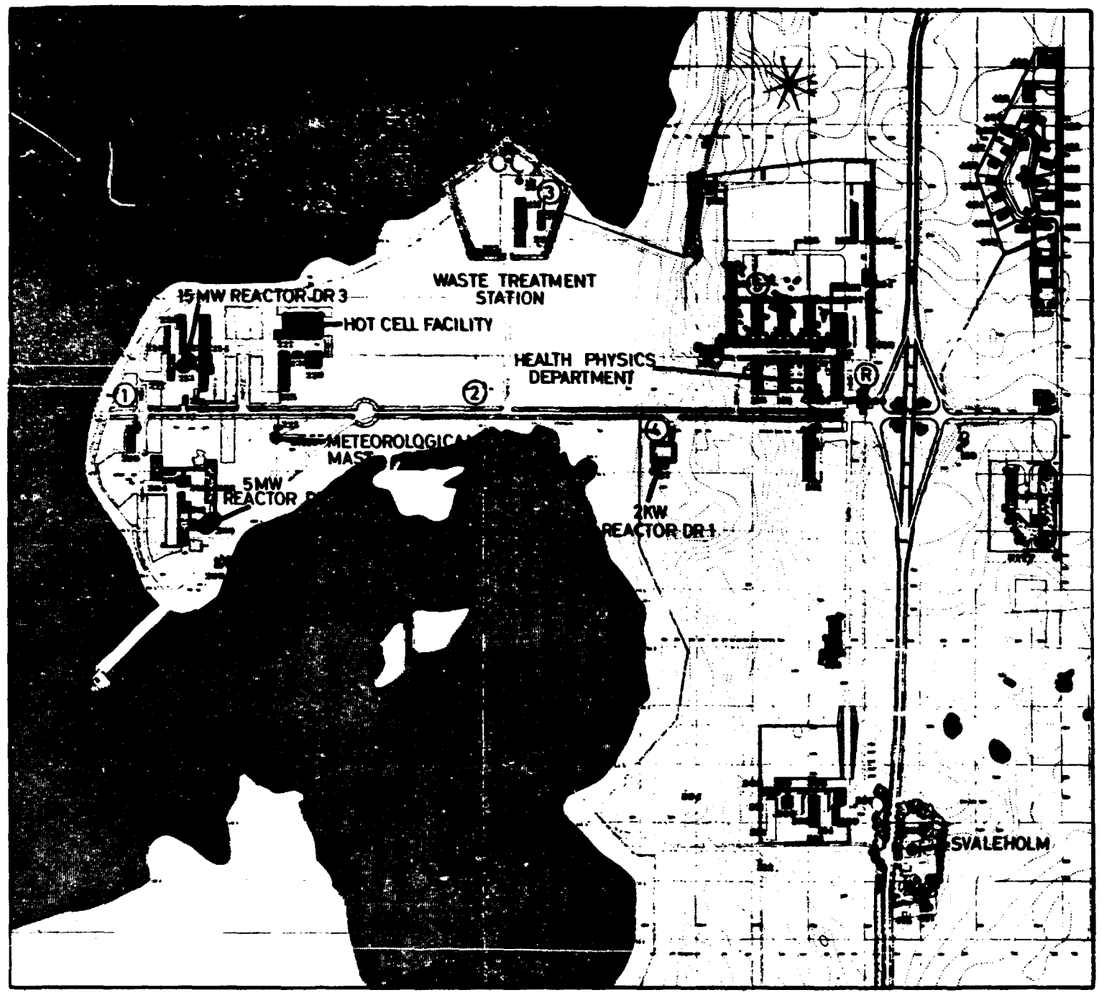

Fig. 3.1.2.1. The Risö Research Establishment.

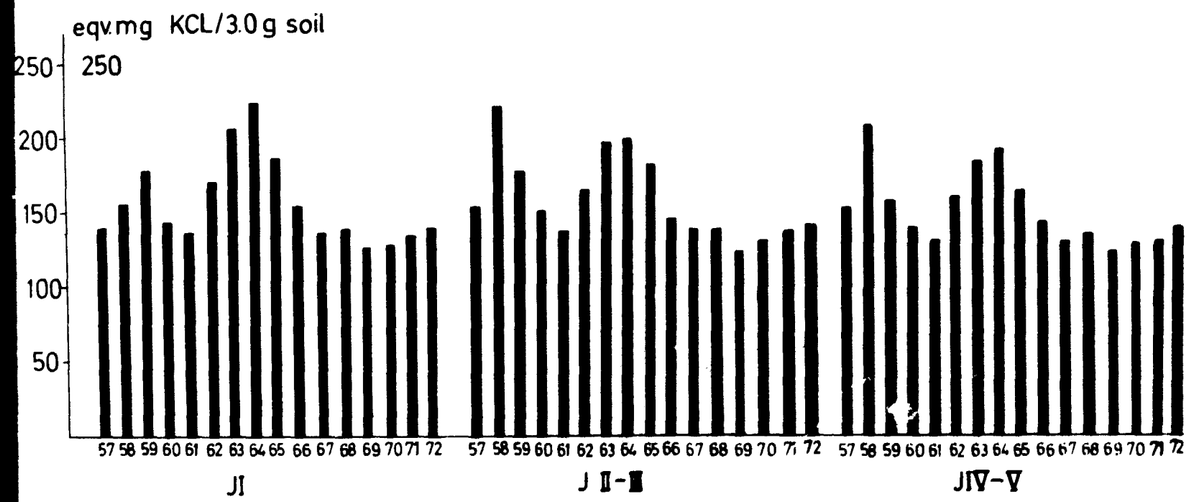

Fig. 3.1.2.3. Mean radioactivity in soil, 1957-72.

3.1.2. Soil

Figs. 3.1.2.1 and 3.1.2.2 (the coloured map) show the sample locations for land samples in the environment of Risø.

The yearly mean for J I in 1972 was 138 eqv. mg KCl/3.0 g soil (in 1971: 140), for J II-III: 140 eqv. mg KCl/3.0 g (in 1971: 141) and for J IV-V: 138 eqv. mg KCl/3.0 g (in 1971: 139). Fig. 3.1.2.3 shows the mean levels of radioactivity in soil since 1957.

3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1972. The mean value for the year was 0.20 eqv. mg KCl/m^3 as compared with 0.21 eqv. mg KCl/m^3 in 1971.

Fig. 3.1.3.2 shows the mean FP levels in air since 1957.

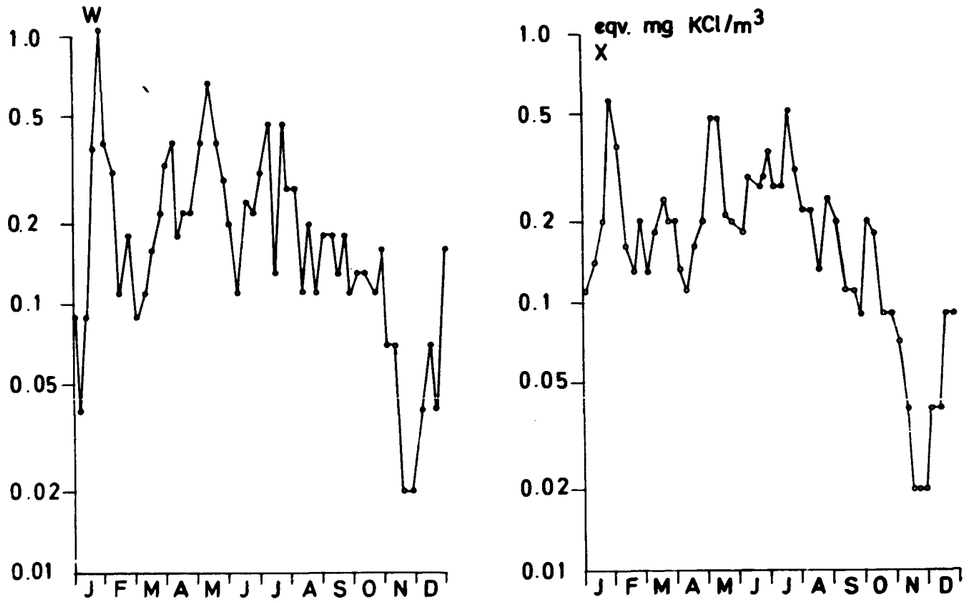

Fig. 3.1.3.1. Control chart for LF, 1972.

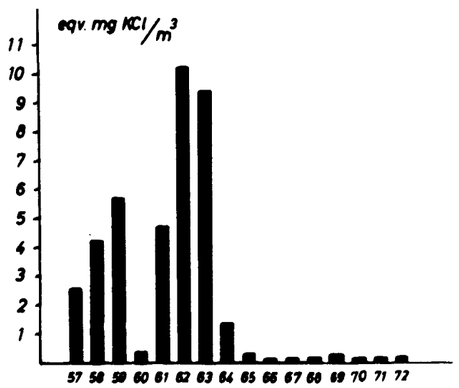

Fig. 3.1.3.2. Mean radioactivity in air, 1957-72.

3.1.4. Bed Soil from the Fjord

The mean activity in bed soil B I was 134 eqv. mg KCl/3.0 g ash in 1972 as compared with 151 eqv. mg KCl/3.0 g in 1971. Fig. 3.1.4.1 shows the mean levels for B I since 1957.

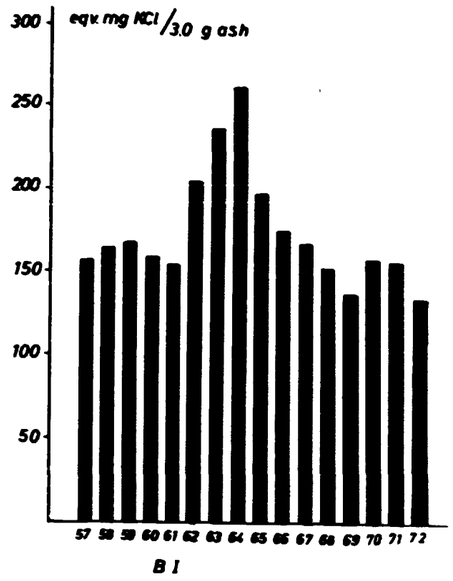

Fig. 3.1.4.1. Mean radioactivity in bed soil, 1957-72.

3.1.5. Fish

No fish samples from Roskilde Fjord were measured in 1972.

3.1.6. Grass

The mean values were in 1972 for PG I: 21 eqv. mg KCl/0.1 g grass ash (in 1971: 46), for PG II-III: 15 eqv. mg KCl/0.1 g (in 1971: 36) and for PG IV-V: 14 eqv. mg KCl/0.1 g (in 1971: 31). Fig. 3.1.6.1 shows the mean activities in grass ash since 1957.

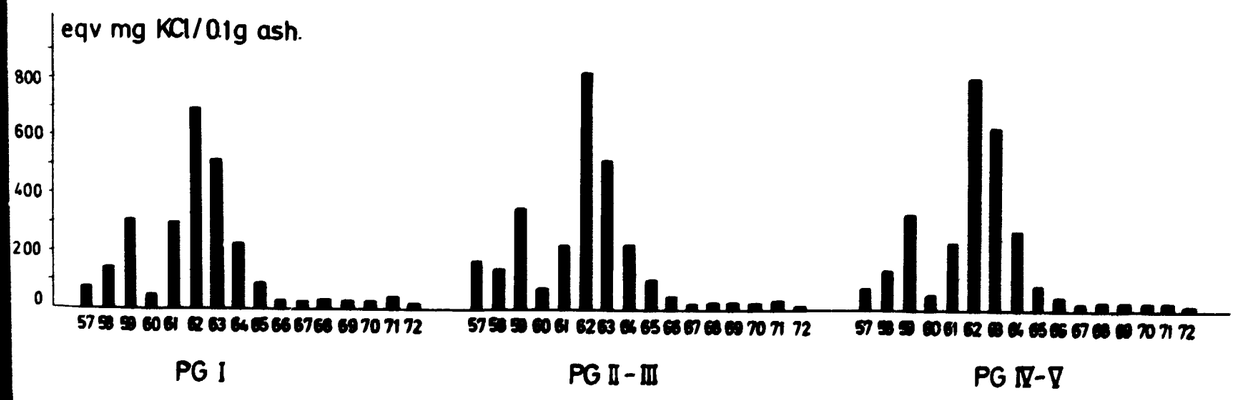

Fig. 3.1.6.1. Mean FP-radioactivity in grass ash, 1957-72.

3.1.7. Sea Plants

The mean FP level in 1971 in Fucus vesicolosus (PH I) was 6 eqv. mg KCl/0.1 g ash (4 in 1971). In Zostera marina (PH III-IX) we found 2 eqv. mg KCl/0.1 g ash in 1972 (4 in 1971).

3.1.8. Fresh Water

Fig. 3.1.8.1 shows the control chart for S (cf. fig. 3.1.2.2). The yearly means for D I, D II, D IV, and S in 1972 were 24 eqv. mg KCl/l (1971: 46), 14 eqv. mg KCl/l (1971: 16), 17 eqv. mg KCl/l (1971: 40), and 37 eqv. mg KCl/l (1971: 84) respectively. Fig. 3.1.8.2 shows the activity in drainage water (D) and sewage water (S).

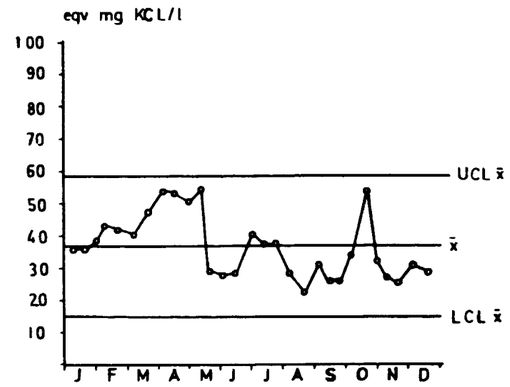

Fig. 3.1.8.1. Control chart for S, 1972.

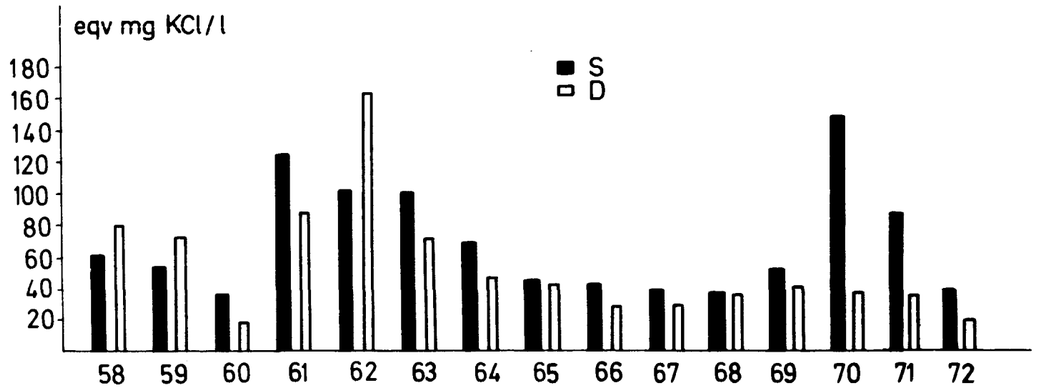

Fig. 3.1.8.2. Mean radioactivity in fresh water, 1958-72.

3.1.9. Rain Water

Figs. 3.1.9.1 and 3.1.9.2 show the specific FP level in and the total fall-out from rain water collected daily at Risø in 1972. The total fall-out in 1972 was measured at $0.031 \cdot 10^6$ eqv. mg KCl/m^2, and the annual mean

concentration in rain water at Risø was 67 eqv. mg KCl/l. In 1971 the corresponding figures were $0.075 \cdot 10^6$ and 162 respectively.

Fig. 3.1.9.3 shows the specific activity in rain water since 1957.

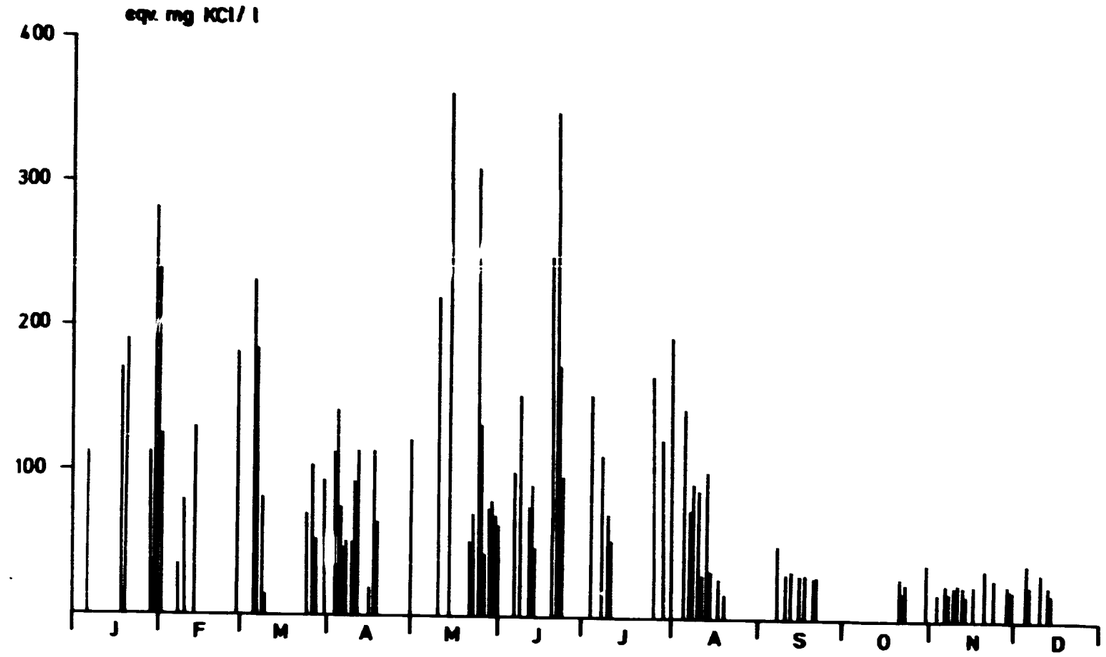

Fig. 3.1.9.1. Concentration of β-activity in precipitation in 1972.

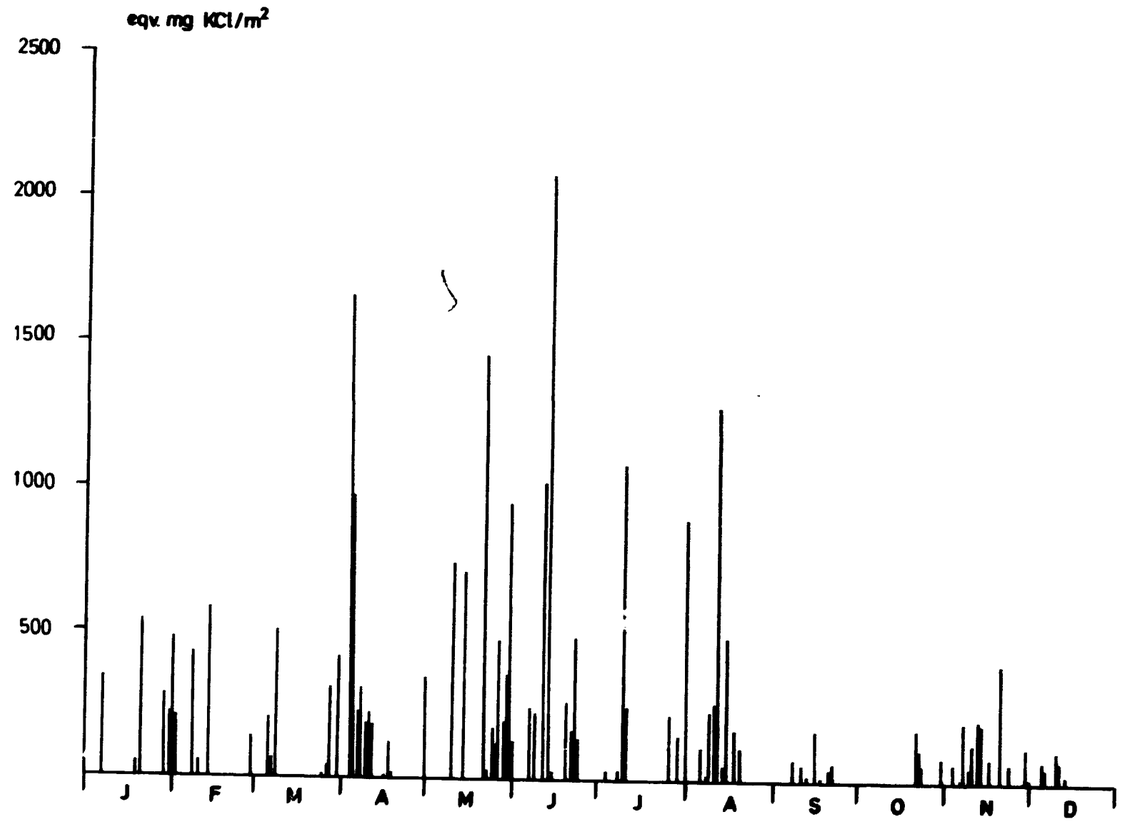

Fig. 3.1.9.2. Total fall-out from precipitation in 1972.

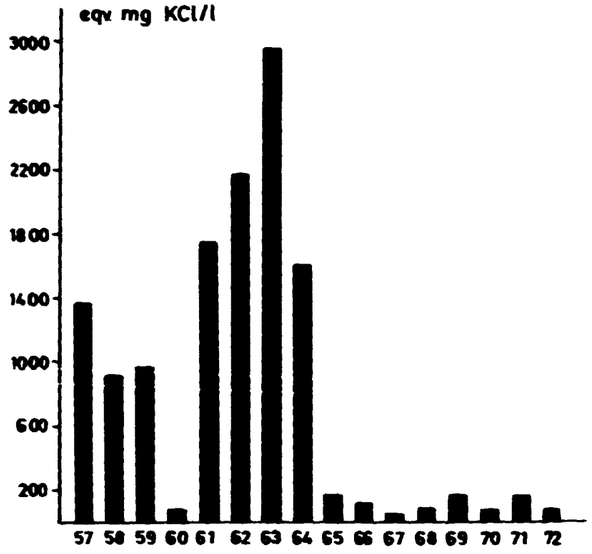

Fig. 3.1.9.3. Specific activity in precipitation, 1957-72.

3.2. Radiochemical β-Analysis

3.2.1. Air

The "big air sampler" described in Risø Report No. 23[1)] has a shunt through which we determine the air volume. As in 1971 we analysed both the shunt filter (I) and aliquots cut out from the main filter (II) to see whether the activity levels were the same in the two filters. As I/II = 0.92 ± 0.07 (1 SE), we conclude as in 1971 that the two filters showed the same levels. We shall report the mean air activity level for 1972 as the mean of the two monthly glass-fibre filter collections and the daily paper filter sampling: 0.8 ± 0.1 pCi $^{90}Sr/10^3m^3$, i.e. 40% of the 1971 level. The mean peak activity of the three collections in 1972 was measured in May to be 1.6 pCi $^{90}Sr/10^3m^3$.

Fig. 3.2.1.1 shows the ^{90}Sr levels in air since 1957.

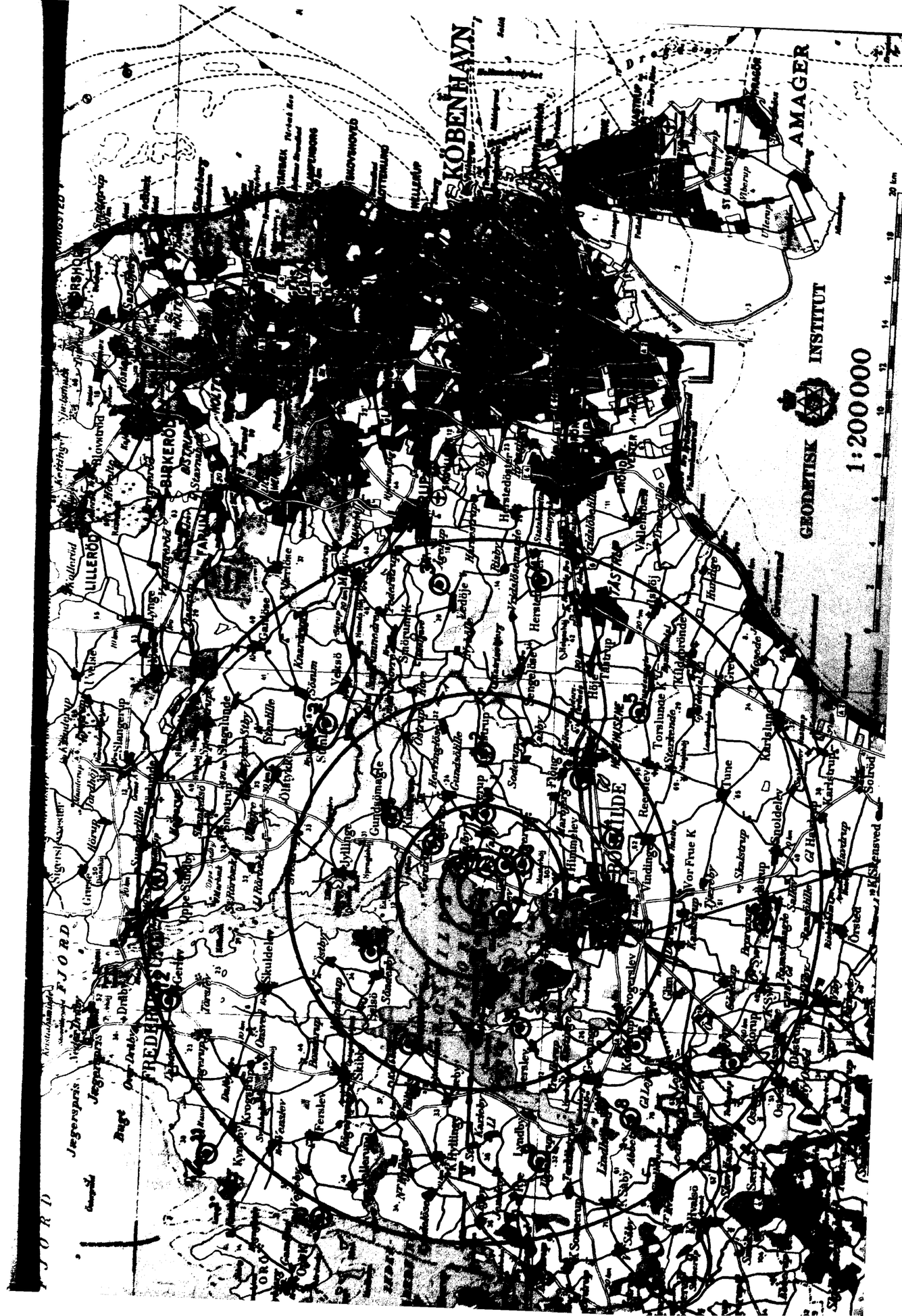

Table 3.2.1

Sr-90 in air collected at Risø in 1972
pCi Sr-90/$10^3 m^3$

Month	Daily air filters Paper	Monthly air filters (glass-fibre filters) I	II
Jan.	0.89	0.41	0.55
Feb.	0.95	0.53	0.78
Mar.	1.1	0.53	0.7-
Apr.	0.90	0.78	1.1
May	1.4	1.6	1.8
June	1.3	1.5	1.4
July	1.5	1.1	1.3
Aug.	0.99	0.53	0.73
Sep.	0.51	0.58	0.42
Oct.	0.50	0.36	0.42
Nov.	0.34	0.21	0.19
Dec.	0.47	0.41	0.32
1972	0.90	0.71	0.81

I: are the normally used shunt filters.

II: are aliquots cut out from the main filters also used for the Cs-137 determination (cf. table 3.3.1).

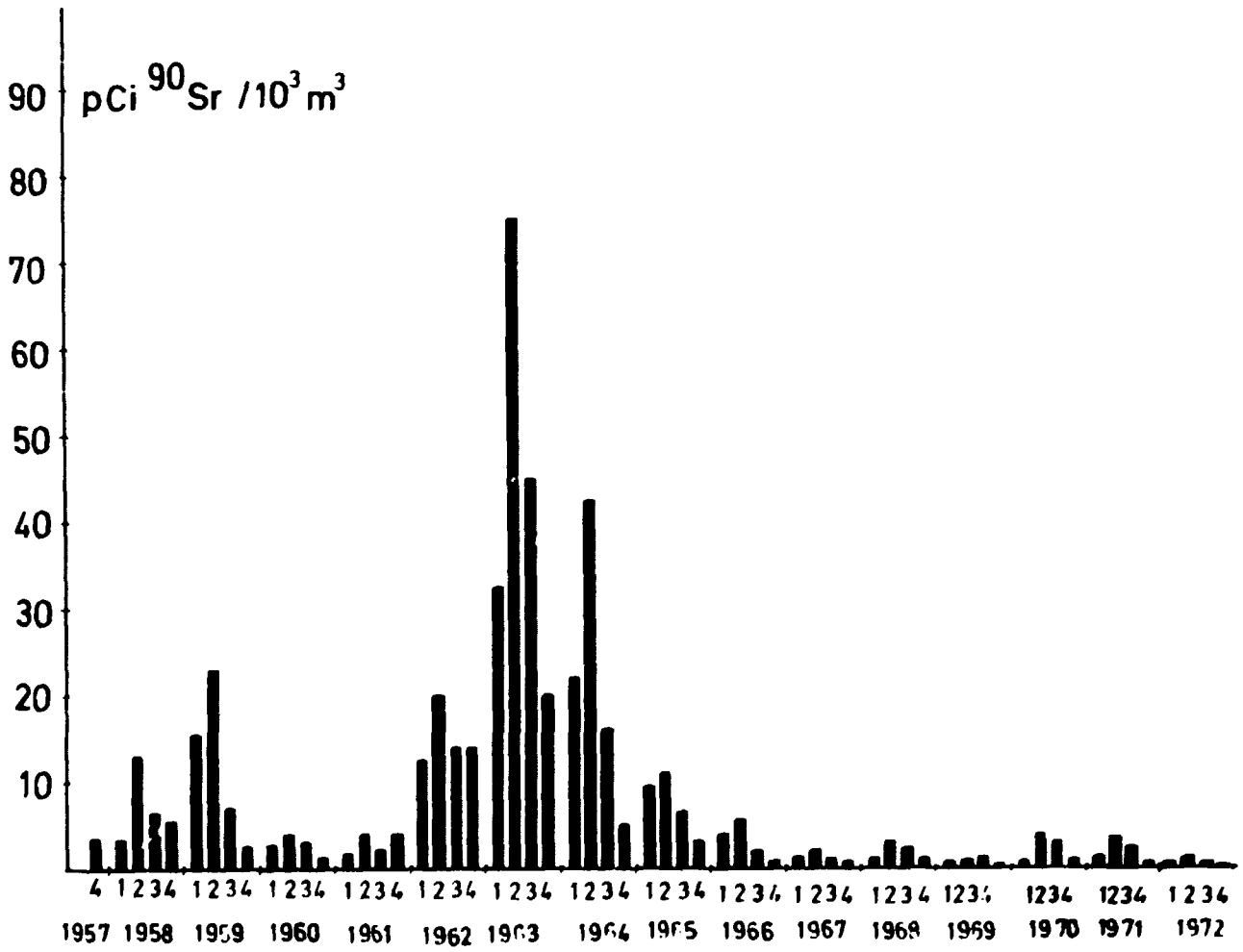

Fig. 3.2.1.1. Strontium-90 in air, 1957-72.

3.2.2. Grass

Table 3.2.2 shows the ^{90}Sr content in grass ash from Zealand in 1972. The mean ^{90}Sr activity was 2.6 pCi ^{90}Sr/g ash or 46 S.U. as compared with 4.1 pCi/g ash or 60 S.U. in 1971, i.e. the 1972 level was 77% of the 1971 level. Fig. 3.2.2.1 shows the ^{90}Sr levels in grass since 1957.

Table 3.2.2

Sr-90 in grass from Zealand, 1972

	pCi Sr-90/g ash	pCi Sr-90/g Ca
Jan.-Mar.	2.31	54
Apr.-June	2.22	43
July-Sep.	3.12	51
Oct.-Dec.	2.89	35
Mean	2.64	46

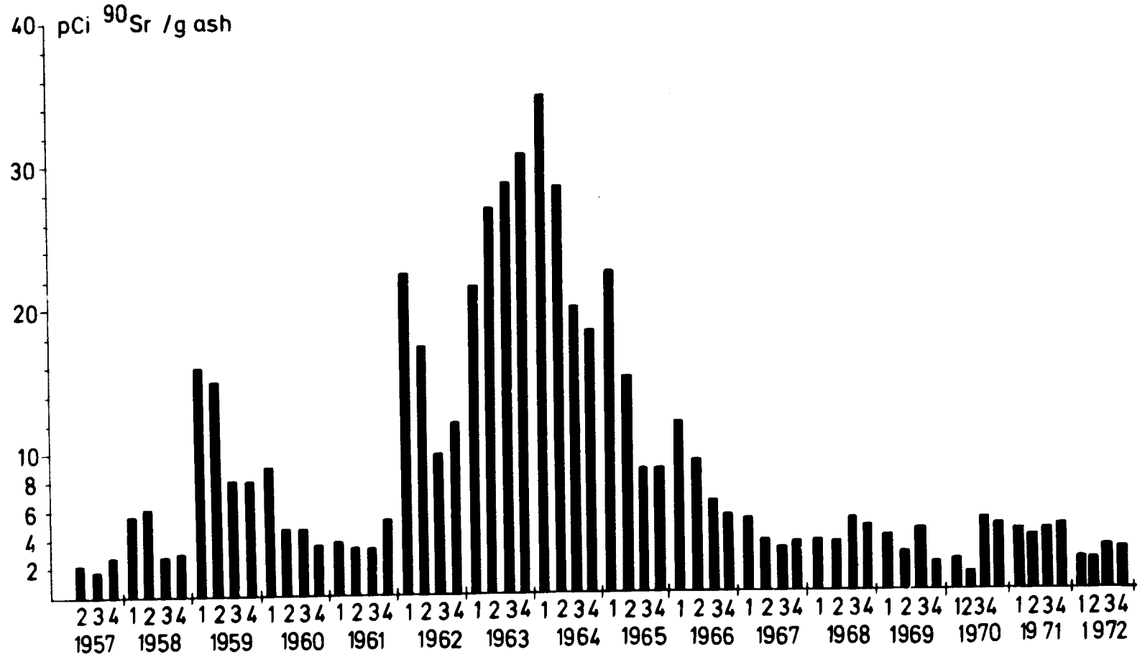

Fig. 3.2.2.1. Strontium-90 in grass ash, 1957-72.

3.2.3. Sea Plants

Fig. 3.2.3 shows the S.U. levels in sea plants since 1959 and table 3.2.3 the results for 1972. The level in Fucus vesicolosus was 16 pCi ^{90}Sr/g Ca, and in Zostera marina we found 5 pCi ^{90}Sr/g Ca.

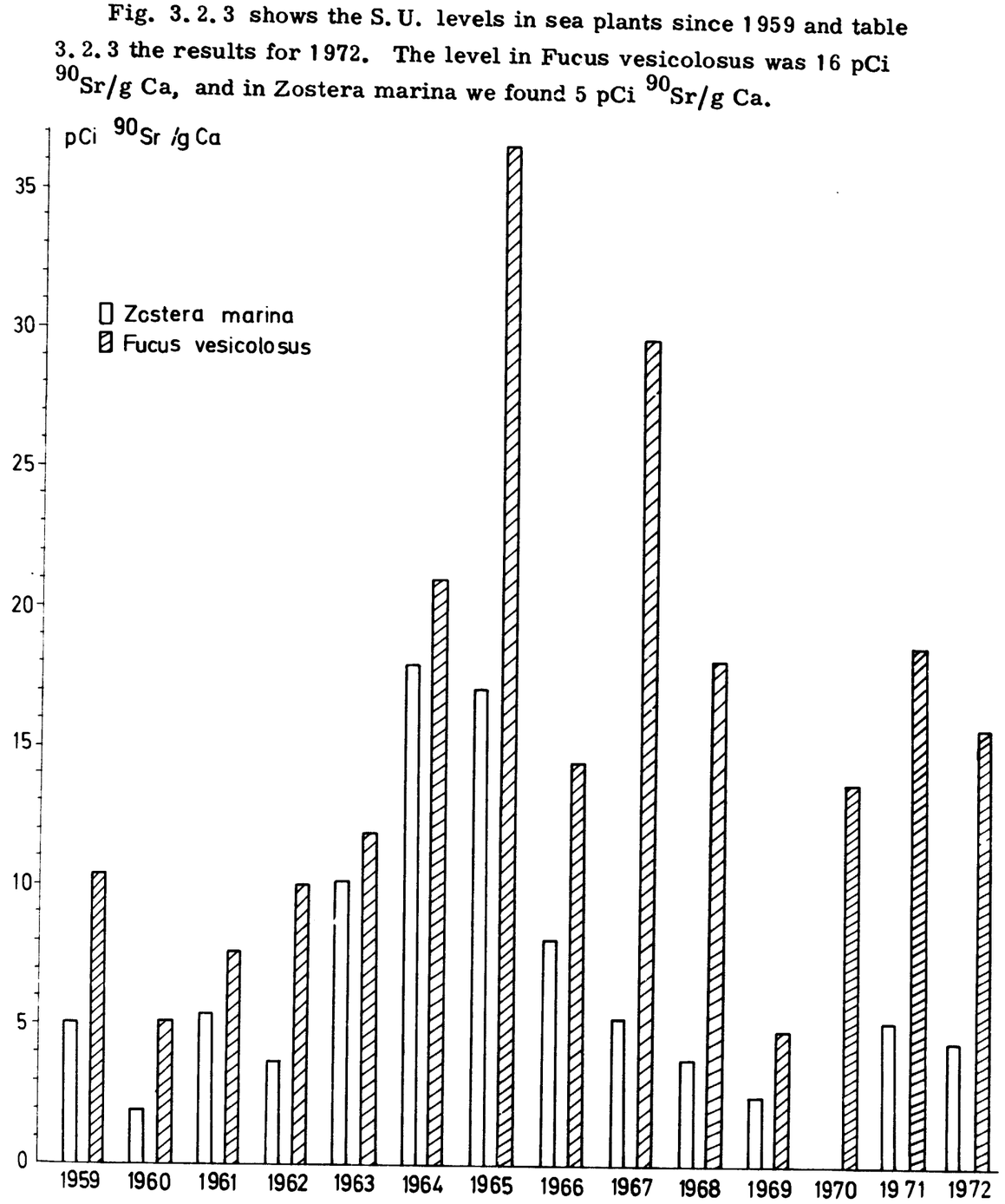

Fig. 3.2.3. Strontium-90 in sea plants, 1959-72.

Table 3.2.3

Sr-90 in sea plants from Roskilde Fjord in 1972

Sampling period	Location	Species	pCi Sr-90/g Ca	pCi Sr-90/g ash	mg Sr/g Ca
Jan. - June	pH III	Zostera marina	6.14	0.34	19.0
July - Dec.	pH I	Fucus vesicolosus	15.9	1.78	40.8
July - Dec.	pH IX	Zostera marina	3.14	0.54	11.0

3.2.4. Rain Water

Table 3.2.4.1 shows the radiostrontium level in rain water collected at Risø in 1972. The total ^{90}Sr fall-out in 1972 was 0.34 mCi $^{90}Sr/km^2$ (467 mm precipitation), and the mean concentration in the rain water was 0.72 pCi $^{90}Sr/l$. In 1971 we measured 0.96 mCi $^{90}Sr/km^2$ (509 mm precipitation and 1.9 pCi $^{90}Sr/l$, i.e. the 1972 levels were 35% of the 1971 figures.

Fig. 3.2.4.1 shows the ^{90}Sr levels in rain water since 1959.

At five sampling locations (1-5) in zone I (cf. fig. 3.1.2.1) ion-exchange columns collected monthly samples of precipitation along with the bottle collectors. The columns have been described earlier (Risø Report No. 41[1]) and are similar to those used in the U.S.A. by HASL[4]. The purpose of this collection is to compare the efficiency of the ion-exchange columns with that of rain bottles as collectors of fall-out. Table 3.2.4.2 shows the results. In 1972 we found no significant difference between the two sampling systems.

Table 3.2.4.1

Sr-90 in monthly samples of rain water collected in rain bottles at Risø in 1972 (sampling area 0.236 m^2)

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	12	1.46	0.018
Feb.	20	0.95	0.019
Mar.	44	0.64	0.028
Apr.	38	0.81	0.031
May	70	0.95	0.067
June	54	1.13	0.061
July	29	1.23	0.036
Aug.	66	0.37	0.024
Sep.	30	0.52	0.016
Oct.	20	0.62	0.012
Nov.	67	0.23	0.015
Dec.	17	0.44	0.0075
1972	Σ 467	$\bar{x}$ 0.72	Σ 0.335

$$\bar{x} = \frac{\Sigma mCi/km^2 \cdot 10^3}{\Sigma mm} \text{ pCi/l}$$

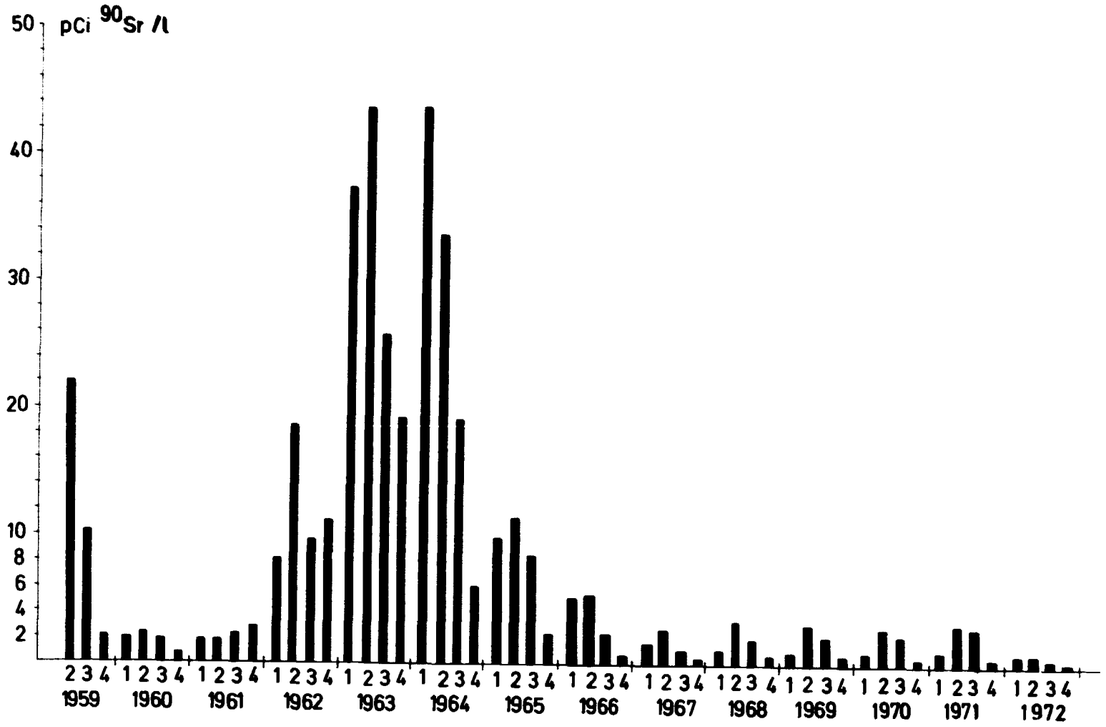

Fig. 3.2.4.1. Strontium-90 in precipitation, 1959-72.

Table 3.2.4.2

Sr-90 in monthly samples of rain water collected in ion-exchange column collectors at Risø in 1972 (sampling area 0.325 m^2)

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	6	2.37	0.014
Feb.	14	1.23	0.017
Mar.	42	0.56	0.023
Apr.	38	0.66	0.025
May	77	0.57	0.044
June	50	1.04	0.052
July	26	1.24	0.032
Aug.	61	0.66	0.040
Sep.	30	0.55	0.016
Oct.	18	0.42	0.0076
Nov.	60	0.22	0.014
Dec.	14	0.76	0.011
1972	Σ 436	$\bar{x}$ 0.68	Σ 0.296

3.2.5. Milk from a farm near Risø

Table 3.2.5 shows the radiostrontium and ^{137}Cs contents in milk collected in 1972 from a farm near Risø. The mean level was 3.9 S.U. as compared with 4.2 S.U. in 1971. Fig. 3.2.5 shows the ^{90}Sr levels in "Risø" milk since 1959. The caesium-137 mean level was 5.2 pCi/l against 7.2 pCi/l in 1971.

Table 3.2.5

Sr-90 and Cs-137 in milk from Risø* in 1972

Month	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l
Jan. - Mar.	Δ3.86±0.19	4.43	6.97
Apr. - June	3.88±0.11	3.59	5.70
July - Sep.	5.36	3.35	5.43
Oct. - Dec.	2.44	1.52	2.52
1972	3.89	3.22	5.16

*The milk was collected from the milk-producing farm nearest to Risø.

Δtriple determinations.

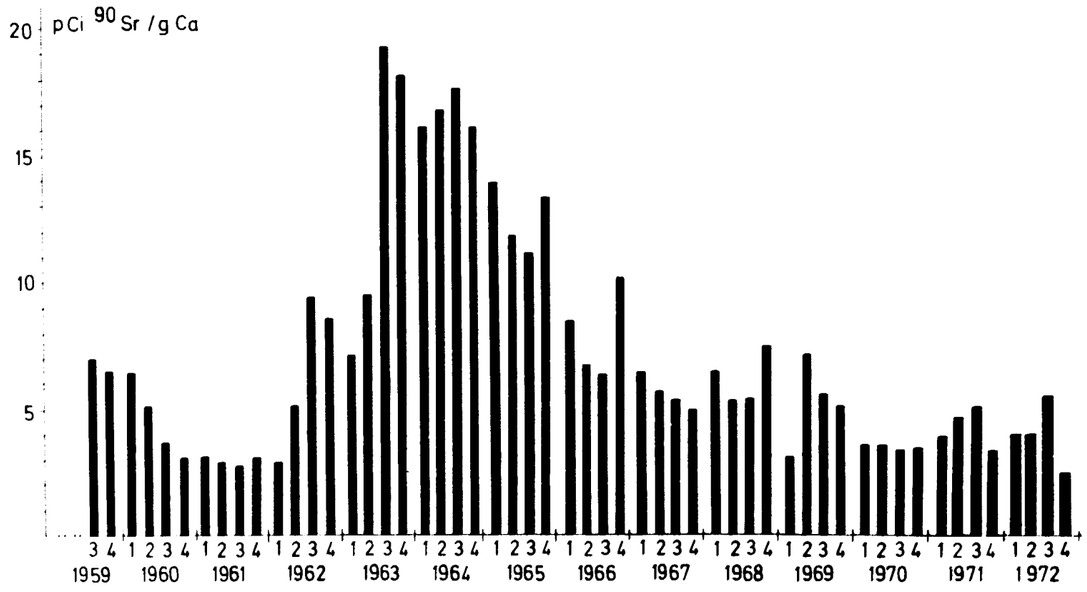

Fig. 3.2.5. Strontium-90 in milk from the Risø neighbourhood, 1959-72.

3.3. γ-Spectroscopy of Air Samples. Some Nuclear Explosions in 1971

As in 1962-1971, half-weekly samples of air were collected by means of the air sampler described in Risø Report No. 23[1]. The half-weekly filters were measured on a 30 cm^3 Ge(Li) detector[8]. Table 3.3.1 shows the monthly means of the ^{137}Cs determinations. The peak value was observed in May (cf. also ^{90}Sr in air, table 3.2.1). The mean level in 1972 was 50% of the 1971 mean.

Table 3.3.1

Cs-137 in glass-fibre air filters collected twice a week at Risø in 1972

Month	pCi Cs-137/$10^3 m^3$
Jan.	1.55±0.38
Feb.	1.30±0.15
Mar.	1.10±0.11
Apr.	1.79±0.16
May	2.73±0.48
June	2.09±0.15
July	2.11±0.29
Aug.	1.45±0.13
Sep.	0.74±0.12
Oct.	0.86±0.12
Nov.	0.32±0.05
Dec.	0.38±0.07
1972	1.37

The error term is the S.E. of the mean of the activity found in 8 or 9 filters collected during a month.

4. RADIOSTRONTIUM AND RADIOCAESIUM IN PRECIPITATION, SOIL, AND GROUND WATER IN DENMARK IN 1972

4.1. Strontium-90 in Precipitation

Samples of rain water were collected in 1972 from the ten State experimental farms (cf. fig. 4.1.1) in accordance with the principles laid down in Risø Report No. 63, p. 51[1].

Table 4.1.1 shows the results of the ^{90}Sr determinations and tables 4.1.2 and 4.1.3 the analysis of variance of the results. The variation with time was highly significant ($P < 99.95\%$). The maximum fall-out occurred in May-June, when the mean content in precipitation was 1.12 pCi $^{90}Sr/l$ (cf. also the air measurements in 3.2.1) and the mean fall-out rate was 0.17 mCi $^{90}Sr/km^2$. Tables 4.1.2 and 4.1.3 show that the variation between locations was not significant. The 1972 mean levels for ten State experimental farms were 0.44 mCi $^{90}/km^2$ and 0.73 pCi $^{90}Sr/l$. In Appendix A the country mean level (area-weighted) is estimated to be 0.46 mCi $^{90}Sr/km^2$ for a mean precipitation amount of 632 mm (area-weighted), i.e. 27% of the fall-out rate in 1971.

Table 4.1.1

Sr-90 fall-out in Denmark in 1972

Period	Unit	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Ledreborg	Mean *
Jan.-Feb.	pCi/l	1.06	0.99	1.06	(1.11)	0.89	0.96	1.26	1.33	1.28	0.35	1.53	1.03
	mCi/km^2	0.039	0.029	0.032	(0.051)	0.039	0.051	0.042	0.043	0.033	0.025	0.041	0.038
Mar.-Apr.	pCi/l	0.92	0.67	0.66	0.83	0.88	0.67	0.74	1.03	0.62	0.82	0.75	0.78
	mCi/km^2	0.084	0.098	0.069	0.11	0.11	0.070	0.079	0.095	0.058	0.074	0.056	0.085
May-June	pCi/l	1.21	1.07	1.15	1.02	1.13	0.82	0.97	1.20	0.99	1.58	1.17	1.12
	mCi/km^2	0.17	0.15	0.20	0.15	0.21	0.16	0.18	0.14	0.17	0.15	0.16	0.17
July-Aug.	pCi/l	0.97	0.68	1.26	1.00	0.69	0.57	0.63	1.00	0.52	0.95	0.69	0.83
	mCi/km^2	0.054	0.10	0.061	0.069	0.11	0.092	0.077	0.081	0.083	0.086	0.073	0.084
Sep.-Oct.	pCi/l	0.31	0.44	0.82	0.66	0.58	0.38	0.60	0.70	0.47	0.74	0.44	0.57
	mCi/km^2	0.017	0.021	0.017	0.034	0.028	0.022	0.029	0.022	0.024	0.037	0.021	0.025
Nov.-Dec.	pCi/l	0.24	.22	0.24	0.27	0.23	0.30	0.32	0.36	0.30	0.29	0.24	0.27
	mCi/km^2	0.040	0.0511	0.031	0.0605	0.045	0.039	0.026	0.029	0.029	0.0400	0.024	0.039
1972	pCi/l $\bar{x}$	0.75	0.61	0.81	0.71	0.72	0.62	0.75	0.94	0.66	0.77	0.76	0.73
	mCi/km^2 Σ	0.434	0.449	0.410	0.475	0.542	0.434	0.433	0.410	0.397	0.412	0.375	0.44
mm precipitation Σ		577	742	507	670	758	701	577	434	600	536	493	610

*Ledreborg not included in mean. Figures in brackets calculated from VAR 3 [12].

Table 4.1.2

Analysis of variance of ln pCi Sr-90/l precipitation in 1972 (from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	0.8403	10	0.0840	1.28	>70%
Betw. months	17.2660	5	3.4532	52.64	>99.95%
Remainder	3.2136	49	0.0656		

Table 4.1.3

Analysis of variance of ln mCi Sr-90/km^2 precipitation in 1972 (from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	0.8025	10	0.0802	1.85	>90%
Betw. months	30.1100	5	6.0220	139.08	>99.95%
Remainder	2.1239	49	0.0433		

A comparison between the amounts of precipitation found in the rain gauges used by the Danish Meteorological Institute and the amounts collected in our rain bottles at the same locations showed in 1972 a mean ratio of 1.00 ± 0.04 (1SE) between the two sampling systems.

4.2. Strontium-90 and Caesium-137 in Soil

As in previous years, soil was collected with a view to estimating the accumulated fall-out. As previously, the samples were collected in September from uncultivated areas all over the country (cf. fig. 4.1.1), and as in 1970 and 1971 down to a depth of 30 cm. One sample was also collected from 30 to 50 cm's depth.

Tables 4.2.1 - 4.2.4 shows the ^{90}Sr results. The mean value at the State experimental farms in September 1972 was 52 mCi $^{90}Sr/km^2$. However, this value should be recalculated to a depth of 20 cm before we compare with the results of the years previous to 1970 (cf. fig. 4.2). From 0-20 we estimated 46 mCi $^{90}Sr/km^2$, ("0-20 cm" is approx. 89% of "0-30 cm" according to Risø Report No. 265[1]).

The 1972 levels were nearly equal to the 1971 figures (0-30: 54, and 0-20 cm: 47 mCi $^{90}Sr/km^2$).

From precipitation data [1,17], the accumulated fall-out in Denmark in 1972 was calculated to be 53 mCi/km^2, i.e. nearly equal to the level found in table 4.2.1.

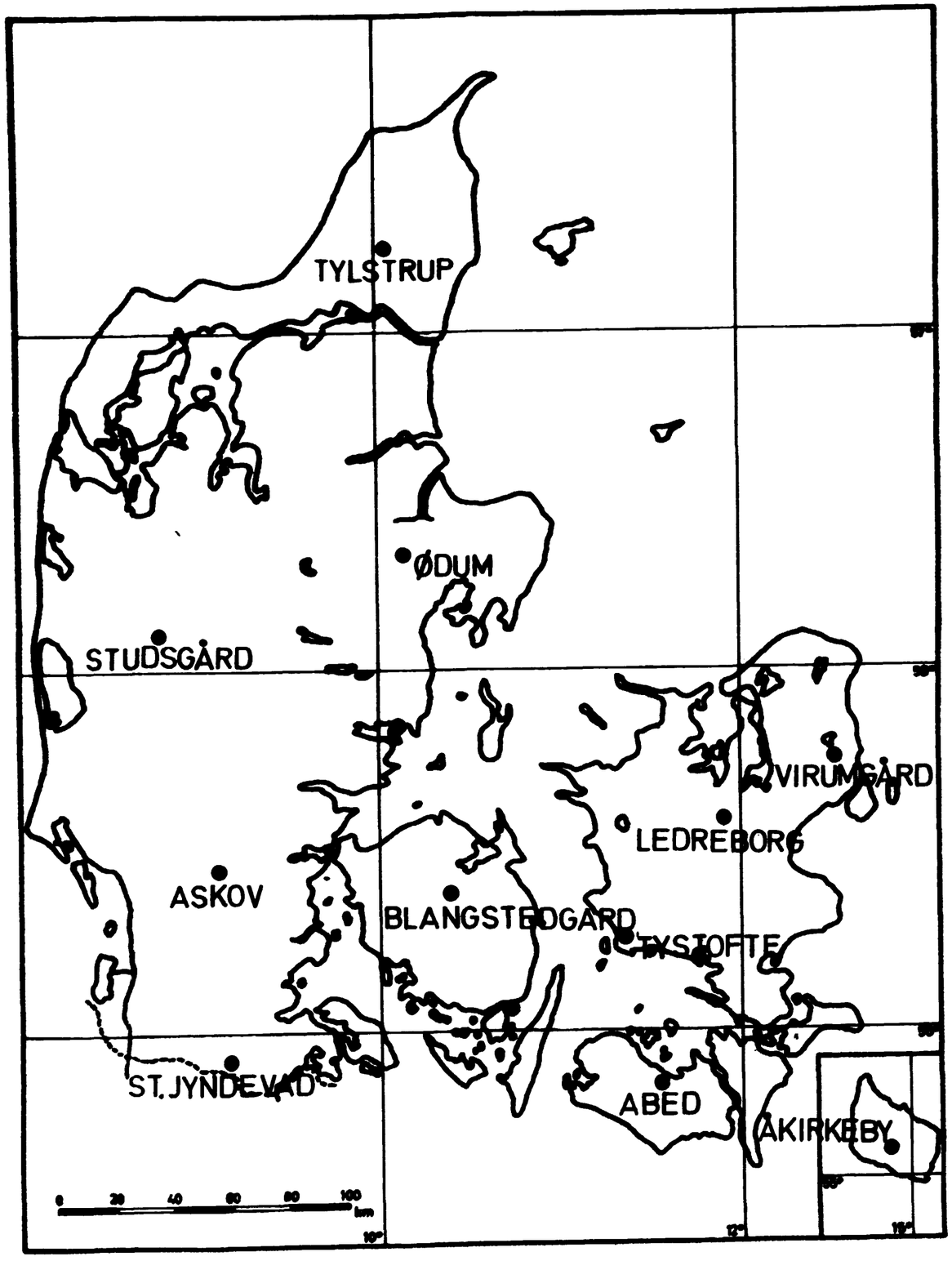

Fig. 4.1.1. State experimental farms in Denmark.

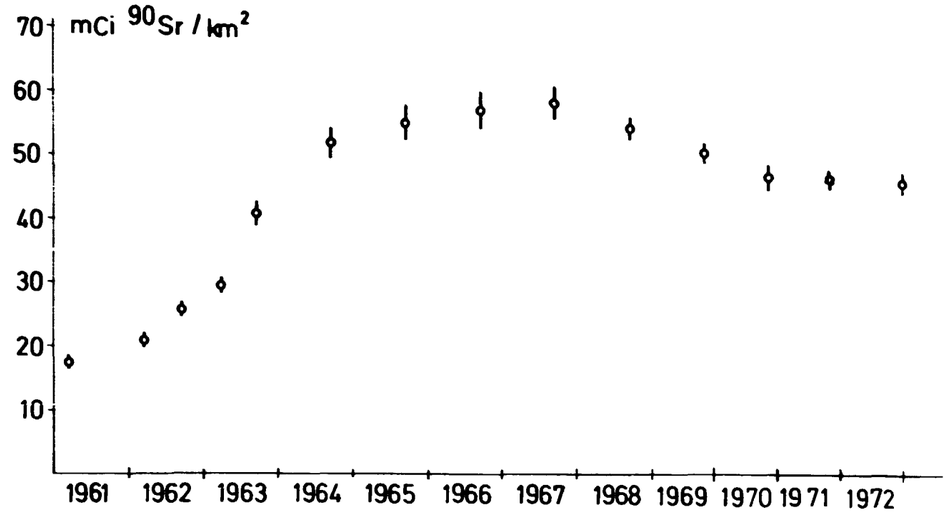

Fig. 4.2. Accumulated ^{90}Sr fall-out in Danish soil, collected at the State experimental farms, 1961-72. 0-20 cm (1 S.E. indicated).

Table 4.2.1

Sr-90 in soil collected at the state experimental farms in September 1972
(0-30 cm)

	Tylstrup	Studs-gård	Ødum	Askov	St. Jyn-devad	Blang-stedgård	Tystofte	Virum-gård	Abed	Akirkeby	Mean	SD	SE
mCi Sr-90/km^2	44±4	72±8	* 44±2	58±2	70±5	39±3	41±4	51±2	53±2	* 48±1	52	12	4
pCi Sr-90/kg	103±9	189±21	$^{\Delta}$109±6	137±5	134±10	122±8	85±8	136±6	221±6	$^{\Delta}$139±3	138	40	13

* Σ 3 sections

$^{\Delta}$ $\bar{x}$ 3 sections weighted

All determinations were triple except Blangstedgård which was quadruple.

The error terms are the S.E.'s of the means.

Table 4.2.2

Sr-90 in soil collected from the surroundings of Roskilde in September 1972

	Bolund	Ledreborg (Roskilde Fælled)	Skydebanen	Mean	SD	SE
mCi Sr-90/km^2	43±3	* 55±1	47±2	48	6	4
pCi Sr-90/kg	162±9	$^{\Delta}$145±2	135±5	147	14	8

* Σ 3 sections

$^{\Delta}$ $\bar{x}$ 3 sections weighted

Table 4.2.3

Sr-90 in soil collected at the state experimental farms in 3 or 4 sections in September 1972

mCi Sr-90/km^2	Ødum	Akirkeby	Ledreborg (Roskilde Fælled)
0-10 cm	24±2	24±1	30±0
10-20 cm	17±1	19±1	18±1
20-30 cm	2.4±0.6	4.5±0.2	6.6±0.3
Σ 0-30 cm	43.4	47.5	54.6
30-50 cm	5.2±1.1		
All determinations were triple			

Table 4.2.4

Sr-90 in soil collected at the state experimental farms in 3 or 4 sections in September 1972

pCi Sr-90/kg	Ødum	Akirkeby	Ledreborg (Roskilde Fælled)
0-10 cm	252±20	261±9	279±4
10-20 cm	108±4	118±6	140±7
20-30 cm	16.5±3.7	51±2	49±3
$\bar{x}$ 0-30 cm	109	139	145
30-50 cm	17.0±2.8		
All determinations were triple			

Table 4.2.5

Cs-137 in soil collected at the state experimental farms in September 1972 (0-30 cm)

	Tvistrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Akirkeby	Mean	SD	SE
mCi Cs-137/km^2	92	119	*113	124	126	65.6	81	100	90	*106	102	20	6
pCi Cs-137/kg	217	309	Δ283	295	240	208	168	266	377	Δ307	267	61	19
g K/kg	14.5	6.1	Δ16.2	13.7	8.3	15.9	18.6	22.1	12.4	Δ19.0	14.7	4.9	1.5
* Σ 3 sections													
Δ $\bar{x}$ 3 sections weighted													

As in previous years ^{137}Cs was also measured (cf. tables 4.2.5-4.2.8). The expected ratio between ^{137}Cs and ^{90}Sr in a soil column containing all ^{137}Cs and ^{90}Sr fall-out is 1.6 - 1.7 In the soil samples we have collected since 1969 the $^{137}Cs/^{90}Sr$ ratios have been significantly higher than the expected value. In Risø Report No. 265[1] we have discussed the reasons for this discrepancy.

In 1972 the $^{137}Cs/^{90}Sr$ ratios (cf. tables 4.2.10-4.2.12) were significantly lower than in 1971, although still higher than the expected ratio. The lower ratios may have two causes. Firstly most of the 1972 samples were collected in one section (0-30 cm) and not as in 1971 in three sections, and secondly the samples were collected with greater care than in 1971, especially with a view to avoiding contamination of the deeper soil layers with surface soil, which shows the highest $^{137}Cs/^{90}Sr$ ratio. We still believe that the main reason for the too high $^{137}Cs/^{90}Sr$ ratios in soil is due to contamination of the lower parts of the soil samples with surface soil.

Table 4.2.6

Cs-137 in soil collected from the surroundings of Roskilde in September 1972

	Bolund	Ledreborg (Roskilde Fælled)	Skydebanen	Mean	SD	SE
mCi Cs-137/km^2	78	*98	77	84	12	7
pCi Cs-137/kg	289	Δ252	216	256	36	21
g K/kg	17.2	Δ19.8	19.4	18.8	1.4	0.8
* Σ 3 sections						
Δ $\bar{x}$ 3 sections weighted						

Table 4.2.7

Cs-137 in soil collected at 3 state experimental farms in 3 or 4 sections in September 1972

mCi Cs-137/km^2	Ødum	Akirkeby	Ledreborg (Roskilde Fælled)
0-10 cm	86	68	64
10-20 cm	23	31	24
20-30 cm	3.9	6.0	10.3
Σ 0-30 cm	113	106	98
30-50 cm	6.5		

Table 4.2.8

Cs-137 in soil collected at 3 state experimental farms in 3 or 4 sections in September 1972

pCi Cs-137/kg	Ødum	Åkirkeby	Ledreborg (Roskilde Fælled)
0-10 cm	892	742	590
10-20 cm	146	194	199
20-30 cm	27	67	71
weighted $\bar{x}$	283	307	262
30-50 cm	19		

Table 4.2.9

K-40 in soil collected at the state experimental farms in 3 or 4 sections in September 1972

g K/kg	Ødum	Åkirkeby	Ledreborg (Roskilde Fælled)
0-10 cm	14.8	20.0	19.8
10-20 cm	17.9	19.2	19.7
20-30 cm	15.2	17.5	19.9
weighted $\bar{x}$	16.2	19.0	19.8
30-50 cm	10.1		

Table 4.2.10

The ratio Cs-137/Sr-90 in soil (0-30 cm) from the State Experimental Farms, 1972 (from tables 4.2.1 and 4.2.5)

Tylstrup	Studs-gård	Ødum	Askov	St. Jyn-devad	Blang-stedgård	Tystofte	Virum-gård	Abed	Åkirkeby	Mean	SD	SE
2.09	1.65	2.57	2.14	1.80	1.68	1.98	1.96	1.70	2.21	1.98	0.29	0.09

Table 4.2.11

The ratio Cs-137/Sr-90 in soil from different depths collected at 3 state experimental farms, 1972 (from tables 4.2.3 and 4.2.7)

	Ødum	Åkirkeby	Ledreborg
0-10 cm	3.58	2.83	2.13
10-20 cm	1.35	1.63	1.33
20-30 cm	1.63	1.33	1.56
0-30 cm	2.60	2.23	1.79
30-50 cm	1.25		

Table 4.2.12

The ratio Cs-137/Sr-90 in soil (0-30 cm) from the surroundings of Roskilde, 1972 (from tables 4.2.2 and 4.2.6)

Bolund	Ledreborg (Roskilde Fælled)	Skydebanen	Mean	SD	SE
1.81	1.78	1.64	1.74	0.09	0.05

Table 4.2.13.

K-40 in soil collected at 3 state experimental farms in 3 or 4 sections in September 1972

g K/kg	Ødum	Åkirkeby	Ledreborg (Roskilde Fælled)
0-10 cm	14.8	20.0	19.8
10-20 cm	17.9	19.2	19.7
20-30 cm	15.2	17.5	19.9
weighted $\bar{x}$	16.2	19.0	19.8
30-50 cm	10.1		

4.3. Strontium-90 in Ground Water

As in previous years, ground water was collected in March from the nine locations selected by L. J. Andersen, M. Sc., Geological Survey of Denmark, in 1961.

Fig. 4.3.1 shows the sample locations and table 4.3.1 the results of the ^{90}Sr analyses (cf. also 5.8.4).

The median level of ^{90}Sr in 1972 was unchanged from 1971. The highest level is still found at Feldbak. Fig. 4.3.2 shows the median levels in Danish ground water since 1961.

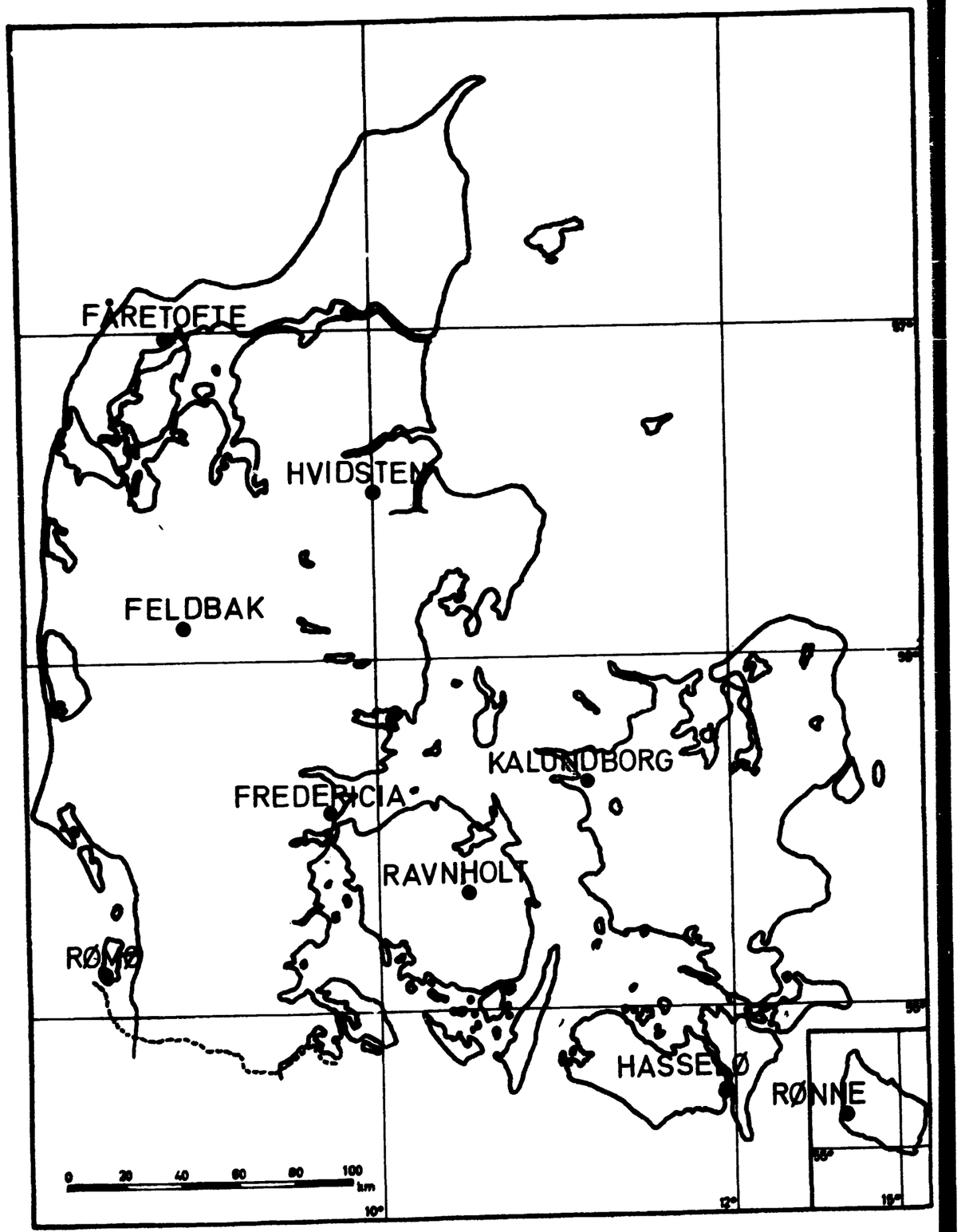

Fig. 4.3.1. Ground-water sampling locations in Denmark.

Table 4.3.1

Sr-90 in ground water collected in March 1972

Location	pCi Sr-90/l	pCi Sr-90/g Ca	g Ca/l
Hvidsten	0.005	0.08	0.066
Feldbak	0.71	22.8	0.031
Rømø	0.008 A	0.2	0.038
Rønne	0.023 A	0.9	0.027
Hasselø	0.004	0.03	0.149
Fåretofte	0.004	0.03	0.139
Kalundborg	0.076	0.6	0.130
Ravnholt	0.010 B	0.08	0.125
Fredericia	0.018 A	0.2	0.080
Mean	0.096	0.5	0.085
Median	0.010	0.2	0.080
A: relative S.D.: 20-33%			
B. relative S.D.: > 33%			

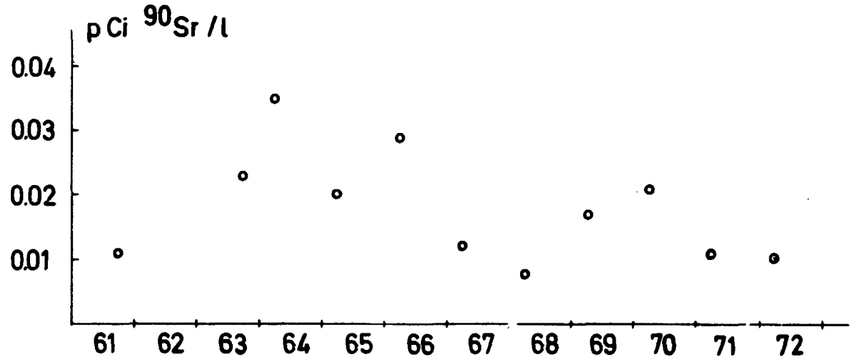

Fig. 4.3.2. Median ^{90}Sr levels in Danish ground water, 1961-72.

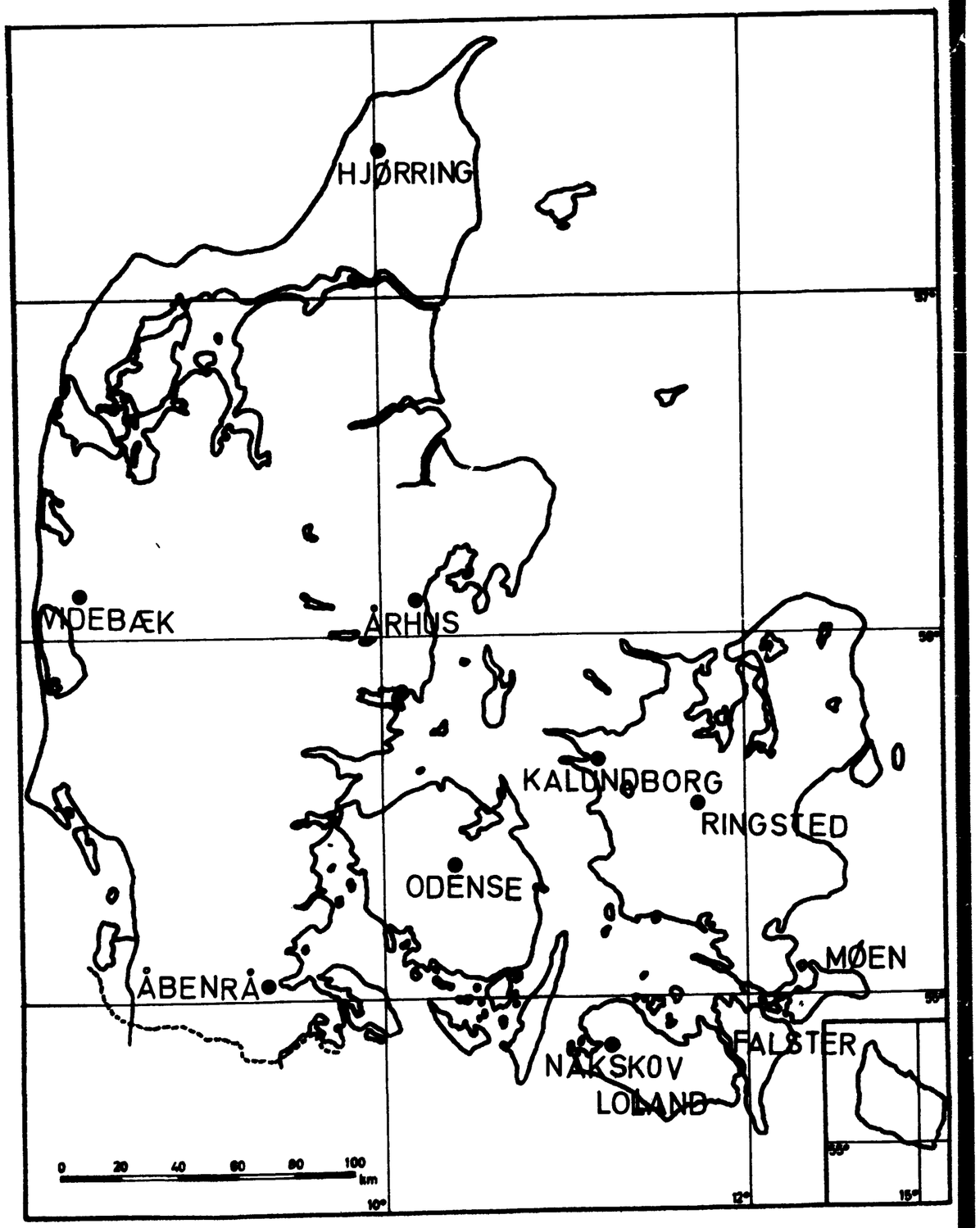

Fig. 5.1.1. Dried-milk factories in Denmark.

5. RADIOSTRONTIUM AND RADIOCAESIUM IN DANISH FOOD IN 1972

5.1. Strontium-90 and Caesium-137 in Dried Milk from the Entire Country

As in the previous years, monthly samples of dried milk were collected from seven locations in Denmark (cf. fig. 5.1.1) and analysed for ^{90}Sr and ^{137}Cs.

Table 5.1.1 shows the results of the ^{90}Sr determinations and table 5.1.2 the analysis of variance of the results. Contrary to previous years the variation between months was significant for S.U. the levels in the first half of the year was higher than in the last half. The S.U. mean level in 1972 was 6.6 pCi $^{90}Sr/g$ Ca or approx. 90% of the 1971 mean. The interaction between locations and months was significant too.

As previously, the milk from eastern Denmark shows significantly lower levels than that from Jutland.

Table 5.1.1

pCi Sr-90/g Ca in Danish dried milk in 1972

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	7.8	7.1	9.8	8.3	6.2	5.0	4.2	6.9
Feb.	10.2	8.2	8.4	9.0	8.2	4.8	5.4	7.7
Mar.	10.1	8.3	8.0	8.2	7.8	5.3	5.1±0.3	7.5
Apr.	9.8	4.2±0.3	12.3	8.3	5.2	8.3±0.2	*4.7±0.3	7.5
May	11.2	6.0±0.1	9.0±0.7	8.2±0.2	6.3±0.7	5.3	Δ5.2±0.5	7.3
June	*9.4±1.1	*7.6±1.0	10.6±2.6	*7.61±0.5	*6.3±0.6	*3.4±0.6	4.1±0.4	7.0
July	*6.9±0.9	7.0	Δ7.6±0.4	*7.3±0.7	*4.8±0.1	5.0±0.7	4.2±0.7	6.1
Aug.	7.6±0.4	*6.6±0.2	*7.0±0.9	6.0±0.9	5.2±0.1	*3.4±0.5	*3.8±0.6	5.7
Sep.	6.0±0.1	6.9±0.2	*7.2±0.5	7.3±0.1	*10.2±1.2	3.6±0.3	3.1±0.5	6.3
Oct.	*6.5±0.2	*5.8±0.2	*7.4±0.2	*7.1±0.1	*5.8±0.3	*4.1±0.5	*3.4±0.3	5.7
Nov.	*7.0±0.7	*6.8±0.7	*8.6±0.2	*6.2±0.2	*4.4±0.1	*3.3±0.2	3.6±0.4	5.7
Dec.	7.4±0.0	*5.7±0.5	7.3±0.3	*7.4±0.5	*4.2±0.6	*3.5±0.2	*4.1±0.2	5.7
Mean	8.3	6.7	8.6	7.6	6.2	4.6	4.2	6.6

*triple analysis

Δquadruple analysis

The error term is the S.E. of the mean. As 1 litre of milk contains 1.2 g Ca, the mean Sr-90 content in Danish milk produced in 1972 was 7.9 pCi/l.

Table 5.1.2

Analysis of variance of ln pCi Sr-90/g Ca in dried milk in 1972
(from table 5.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	12.5580	6	2.0930	30.55	> 99.95%
Betw. months	2.3456	11	0.2132	3.11	> 99.5%
Loc. x months	4.5204	66	0.0685	2.61	> 99.95%
Remainder	2.4961	95	0.0263	-	-

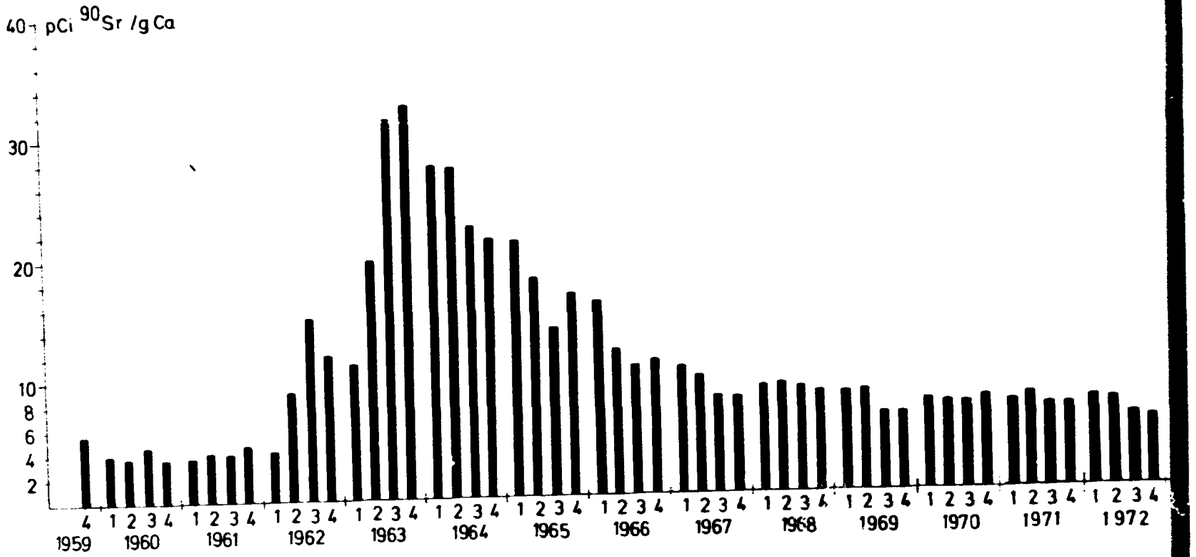

Fig. 5.1.2. Strontium-90 in dried milk, 1959-72.

Table 5.1.3 shows the results of the ^{137}Cs determinations and table 5.1.4 the analysis of variance of the results. Contrary to previous years, the maximum level of ^{137}Cs: 8.2 M.U., was not found in milk from the summer but in milk from February. The M.U. mean level in 1972 was 6.6 pCi ^{137}Cs/g K or 75% of the 1971 level.

Figs. 5.1.2 and 5.1.3 show the quarterly S.U. and M.U. values since October-December 1959 (cf. also Appendix C).

Table 5.1.3.

pCi ^{137}Cs/g K in Danish dried milk in 1972

Month	Kjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	8.7	6.7	12.4.	8.6	6.0	5.5	6.3	7.7
Feb.	8.4	8.9	11.7	10.8	6.7	5.7	5.5	8.2
Mar.	10.3	7.3	10.7	9.8	8.1	4.5	5.8	8.1
Apr.	8.4	6.9	11.5	8.5	6.5	5.1	5.3	7.5
May	9.7±0.1	6.0±0.0	6.3	7.1	4.7	3.8	4.2	6.0
June	9.9	8.2	11.4	7.2	9.2	6.2	A 2.5	7.8
July	8.6	7.1	13.5	11.9	6.0	3.5	A 4.0	7.8
Aug.	8.8	7.7	8.5	10.3	5.1	3.5	3.5	6.8
Sep.	9.2	7.3	5.9	7.6	4.4	4.0	A 6.0	6.3
Oct.	7.4	4.2	7.5	6.3	5.4	2.5	A 2.8	5.2
Nov.	B 2.3	4.0	6.8	6.7	B 1.7	A 2.1	A 2.5	3.7
Dec.	A 6.7	4.5	A 4.1	6.0	B 1.9	2.5	B 1.8	3.9
Mean	8.2	6.6	9.2	8.4	5.5	4.1	4.2	6.6

As 1 litre of milk contains approx. 1.66 g K, the mean ^{137}Cs content in Danish milk produced in 1972 was estimated at 11.0 pCi/l.

A: relative S.D.: 20-33%

B: relative S.D.: > 33%

Table 5.1.4

Analysis of variance of ln Cs-137/g K in Danish dried milk 1972
(from table 5.1.3)

Variation	SSD	f	s^2	v^2	P
Betw. locations	8.9416	6	1.4902	25.17	> 99.95%
Betw. months	7.0684	11	0.6425	10.85	> 99.95%
Remainder	3.9051	66	0.0592		

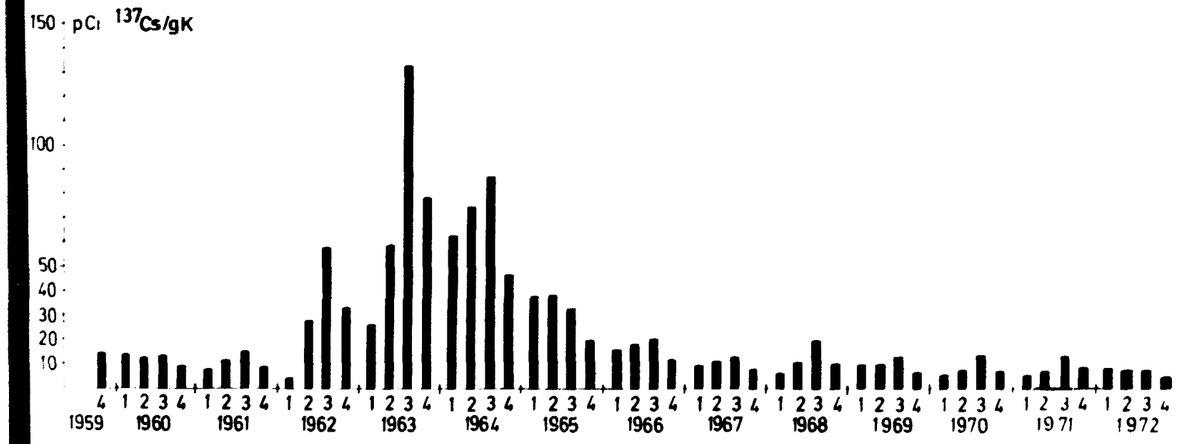

Fig. 5.1.3. Caesium-137 in dried milk, 1959-72.

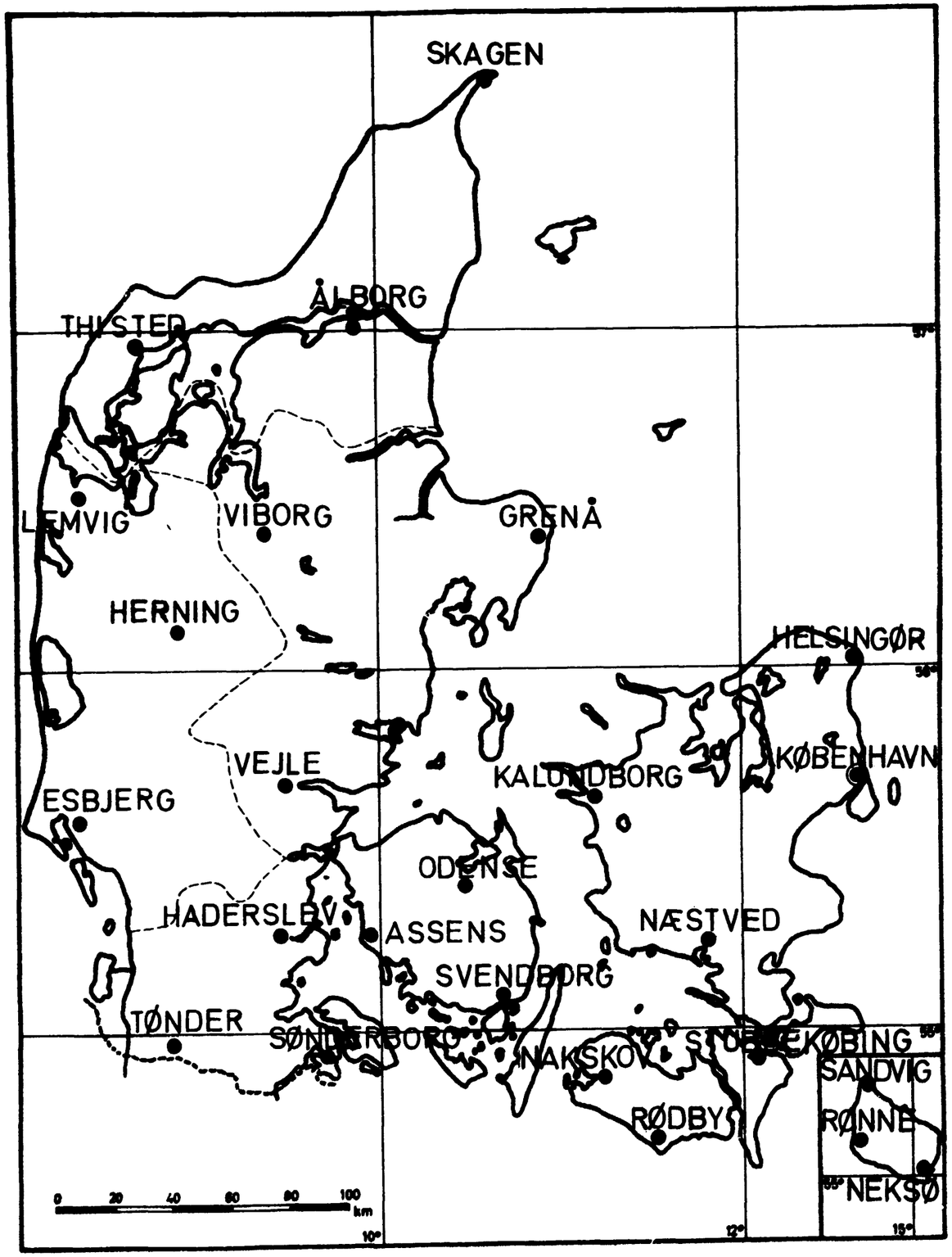

Fig. 5.2.1. Sample locations for fresh milk, bread and total diet (A-towns).

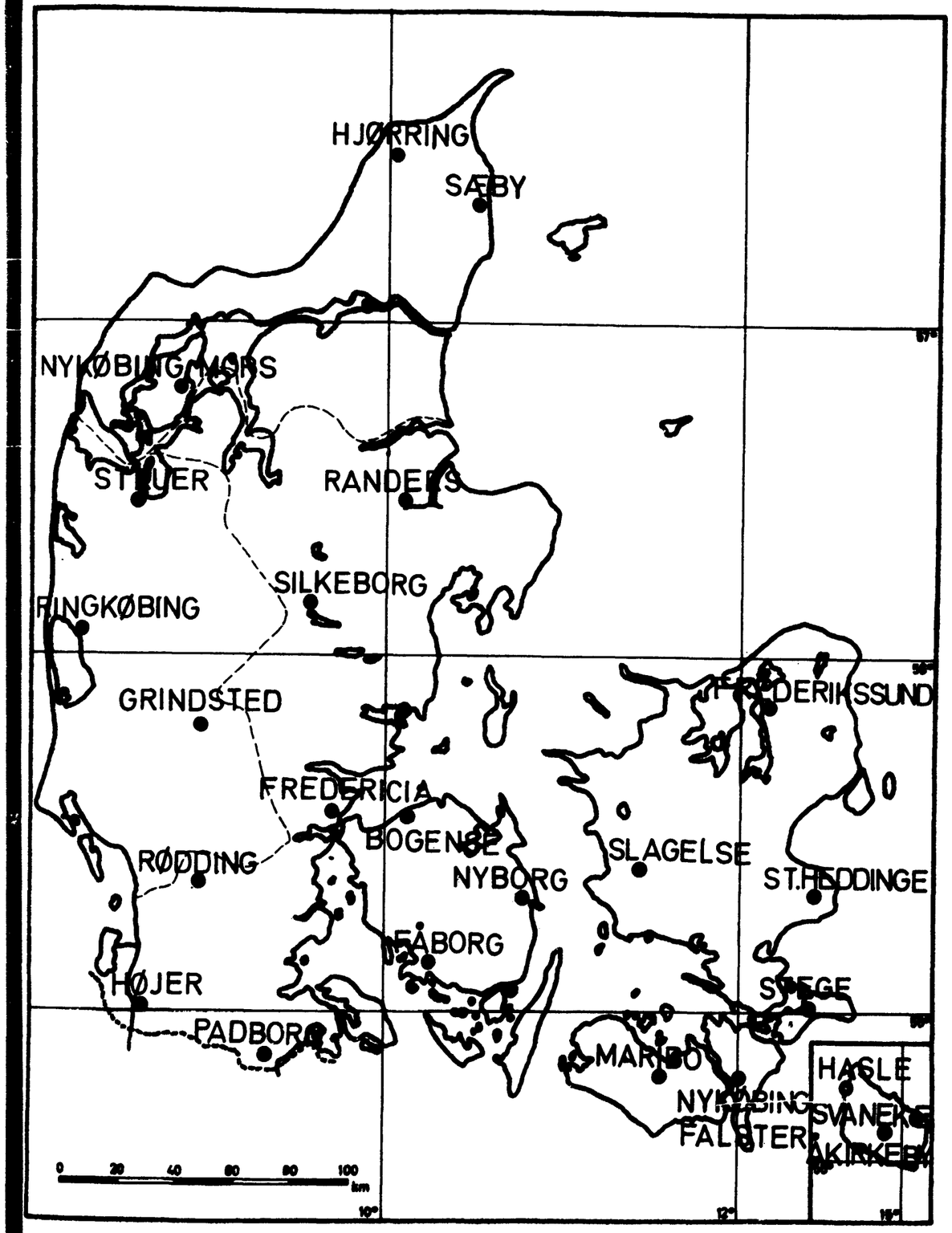

Fig. 5.2.2. Sample locations for fresh milk, bread and total diet (B-towns).

5.2. Strontium-90 and Caesium-137 in Fresh Milk from the Entire Country

The samples of fresh milk were collected in the eight zones and in Copenhagen as previously (cf. figs. 5.2.1 and 5.2.2) in connection with the total-diet collection (cf. 5.7).

Table 5.2.1 shows the results of the determinations of radiostrontium and ^{137}Cs in consumer milk.

The production-weighted means for ^{90}Sr and ^{137}Cs in Danish consumer milk in 1972 collected in June and December were 5.8 S.U. (~7 pCi ^{90}Sr/l) and 4.9 M.U. or 8.0 pCi ^{137}Cs/l respectively.

As previously it seems reasonable to regard the mean of the levels found in June and December as representative of the annual production-weighted mean, as the mean for these two months calculated from the dried-milk data (cf. tables 5.1.1 and 5.1.2) yielded a reasonable estimate of the annual mean for dried milk.

If the figures in tables 5.2.1 are weighted with respect to the population, the country means become 5.2 S.U. and 7.1 pCi ^{137}Cs/l, i.e. a little lower than the production-weighted means.

As compared with dried milk, the fresh milk levels were lower. This is in agreement with earlier observations[1].

Table 5.2.1

Sr-90 and Cs-137 in fresh milk in 1972

Zone	June 1972			December 1972		
	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l
I: N-Jutland	6.65±0.23	8.74	13.3	4.57	4.54	7.62
II: E-Jutland	6.12±0.30	6.27	9.8	5.37	3.91	6.91
III: W-Jutland	7.52±0.1	7.36	11.8	6.10	1.77	3.56
IV: S-Jutland	6.91±0.62	6.52	10.2	6.22	2.38	5.38
V: Funen	4.65±0.11	4.64	7.4	4.81	1.87	3.54
VI: Zealand	4.30±0.23	4.07	6.7	4.77	2.64	4.75
VII: Lolland-Falster	4.43±0.25	2.48	3.9	4.52	1.13	1.88
VIII: Bornholm	5.64±0.39	5.92	9.0	5.83	3.80	4.64
Mean	5.78	5.75	9.0	5.27	2.76	4.78
Copenhagen	4.64±1.6	4.58	7.3	3.76	3.95	5.44
Population-weighted mean	5.52	5.63	8.9	4.79	3.22	5.31
Production-weighted mean	6.30	6.63	10.4	5.36	3.08	5.61

5.3. Strontium-90 and Caesium-137 in Grain from the Entire Country

As in previous years, grain samples were obtained from ten State experimental farms (cf. fig. 4.1.1). Virumgård was replaced by Ledreborg in 1969. Strontium-90 was determined as previously (Risø Report No. 63[1]), and ^{137}Cs was measured on ashed samples by γ-spectrometry on a Ge-detector.

Table 5.3.1 shows the measurements of ^{90}Sr in grain in 1972. According to Appendix B, approx. 1/2 of all rye in Denmark is grown in Jutland and 1/2 in the eastern part of the country. As regards wheat, 4/5 is produced in eastern Denmark and 1/5 in Jutland. In the calculation of the means in tables 5.3.1 and 5.3.4 Jutland is represented by five rye figures and nine wheat figures, while eastern Denmark contributes nine wheat figures and four rye figures. Thus the means in tables 5.3.1-5.3.4 for rye and wheat are higher than the production-weighted means for the country. Table 5.3.2 gives the analysis of variance of the S.U. figures and table 5.3.3 that of the pCi ^{90}Sr/kg grain figures.

Table 5.3.2 shows that the variation in S.U. between species was significant. Wheat showed the highest S.U. levels and barley the lowest. The pCi ^{90}Sr/kg figures also show a significant difference between species. (Oats > rye).

As in previous years, the variation with location was highly significant; the mean pCi ^{90}Sr/kg level for grain from Jutland was approx. twice that in eastern Denmark.

Table 5.3.4 shows the measurements of ^{137}Cs in grain in 1972, table 5.3.5 the analysis of variance of the M.U. figures and table 5.3.6 the analysis of variance of the pCi ^{137}Cs/kg grain figures. The variation between locations was not significant althouth the ^{137}Cs content in grain from Jutland was on the average approx. 1.4 (pCi/kg figures) times as high as the grain level in eastern Denmark. The variation between species was significant. Rye contained as previously more ^{137}Cs than the other grain species.

If the S.U. levels in grain from the harvest of 1971 are compared with the levels from 1971[1], we find the 1972 figures to be 0.75 times the 1971 levels.

The ^{137}Cs content in grain from the 1972 harvest was on the average 0.30 times the 1971 means. The fall-out rate in May-August 1972 was 0.37 times that in May-August 1971. (The period May-August was selected because experiments have shown[10] that the contamination of grain with

Table 5.3.1

Sr-90 in Danish grain in 1972

	Rye		Barley		Wheat		Oats	
	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.
Tylstrup	w: 22±2	w: 71±19	45±1	106±7	s: 55±3	s:114±1	57±4	89±12
Studsgård	s: 26±1 w: 45±3	s: 75±3 w:128±15	65±1	124±3	s: 47±3 w: 61±3	s:149±4 w:195±2	108±3	165±25
Ødum	-	-	14±0	32±0	s: 17±0 w: 14±1	s: 51±1 w: 69±3	18±0	28±1
Askov	34±0	80±7	36±3	74±4	s: 34±1 w: 29±1	s: 94±0 w:110±3	129±1	124±1
St. Jyndevad	w: 45±6	w:110±38	s: 64±1	s:149±2	s: 61±4 w: 90±5	s:177±37 w:276±64	103±1	131±5
Blangstedgård	16±1	34±4	13	27	15±1	53±8	22±1	25±1
Tystofte	w: 23±0	w: 57±4	s: 22±3 w: 23±2	s: 54±8 w: 46±5	s: 24±3 w: 23±3	s: 66±10 w: 81±9	62±4	69±6
Ledreborg	25±2	64±8	22±0	43±0	s: 22±0 w: 31±1	s: 52±4 w: 64±10	23±0	26±0
Abed	-	-	21±1	39±3	s: 19±1 w: 18±2	s: 48±4 w: 37±0	23±2	36±3
Åkirkeby	25±3	72±12	17±0	49±6	s: 21±1 w: 19±2	s: 55±3 w: 59±5	35±4	73±22
Mean	29	77	31	68	33	97	58	77

Table 5.3.2

Analysis of variance of ln S.U. in grain in 1972
(from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
betw. species	2.1555	3	0.7185	5.30	>99%
Betw. locations	23.7713	9	2.6412	19.48	>99.95%
Spec. x loc.	3.3906	25	0.1356	3.32	>99.95%
Remainder	2.3256	57	0.0408		

Table 5.3.3

Analysis of variance of ln pCi Sr-90/kg grain in 1972
(from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	5.2338	3	1.7446	9.87	>99.95%
Betw. locations	23.0381	9	2.5598	14.48	>99.95%
Spec. x loc.	4.4204	25	0.1768	8.25	>99.95%
Remainder	1.2217	57	0.0214		

Table 5.3.4

Cs-137 in Danish grain in 1972

	Rye		Barley		Wheat		Oats	
	pCi Cs-137/kg	M.U.	pCi Cs-137/kg	M.U.	pCi Cs-137/kg	M.U.	pCi Cs-137/kg	M.U.
Tylstrup	w:28.2	w: 6.2	30.1	6.2	s:21.9	s:3.3	A 16.2	A 3.0
Studsgård	s:41.2 w:60.3	s: 7.7 w:12.2	32.5	5.5	s:29.4 w:29.0	s:6.4 w:7.1	20.7	6.5
Ødum	-	-	12.8	2.3	s:10.5 A w:17.5	s:2.2 A w:4.4	A 15.1	A 3.0
Askov	50.0	9.1	A 23.0	A 3.8	s:17.2 w:19.1	s:3.0 w:4.3	52.8	15.4
St. Jyndevad	w:31.4	7.6	s:29.2	s:5.7	s:40.0 w:22.2	s:8.7 w:6.1	22.5	4.9
Blangstedgård	34.8	7.2	9.3	1.8	A 13.5	A 3.0	21.5	4.3
Tystofte	28.4	6.1	s:21.0 w:29.4	s:3.7 w:4.8	s:13.6 w: 9.0 A	s:3.8 w:3.4 A	*61.2±4.6	*11.9±0.6
Ledreborg	35.1	7.4	A 12.5	A 2.3	s:17.2 w:12.5	s:3.1 w:2.3	B 9.8	B 2.3
Abed	-	-	17.2	3.2	s:25.0 w:13.5	s:5.4 w:2.5	A 10.4	A 2.7
Åkirkeby	26.8	7.4	10.4	2.9	s:11.6 w:15.5	s:2.8 w:3.5	16.4	3.8
Mean	37.3	7.9	20.7	3.8	18.8	4.2	24.7	5.8

*triple determinations

A: relative S.D.: 20-33%

B: relative S.D.: >33%

Table 5.3.5

Analysis of variance of ln pCi Cs-137/g K grain in 1972
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	3.0795	3	1.0265	5.75	>99.5%
Betw. locations	4.5490	9	0.5054	2.83	>97.5%
Species x loc.	4.4649	25	0.1786	2.41	>90%
Remainder	0.8900	12	0.0742		

Table 5.3.6

Analysis of variance of ln pCi Cs-137/kg grain in 1972
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	2.6229	3	0.8743	3.88	>97.5%
Betw. locations	4.2483	9	0.4720	2.10	>90%
Species x loc.	5.6314	25	0.2253	3.19	>97.5%
Remainder	0.8478	12	0.0706		

Table 5.3.7

mg Sr/g Ca in grain collected in 1972

	Rye		Barley		Wheat		Oats
	w	s	w	s	w	s	s
Tylstrup	4.0			5.2		4.7	4.0
Studsgård	4.0	4.0		4.0	7.7	7.8	5.0
Ødum				3.6	2.6	2.0	2.2
Askov	2.9			3.9	4.2	5.8	4.0
St. Jyndevad	3.3			4.6	8.2	9.1	4.2
Blangstedgård	1.5			2.2	3.0		3.0
Tystofte	2.8		3.0	3.1	3.9	4.4	3.2
Ledrebord	2.8			2.8	3.3	3.6	1.4
Abed				3.6	4.9	4.5	2.2
Åkirkeby	2.4			2.6	3.5	2.8	1.1

Table 5.3.8

Analysis of variance of ln mg Sr/g Ca in grain in 1972 (from table 5.3.7)

Variation	SSD	f	s^2	v^2	P
Betw. species	2.0217	3	0.6739	9.17	>99.95%
Betw. locations	4.8084	9	0.5343	7.27	>99.95%
Species x loc.	1.8363	25	0.0735	5.56	>99.5%
Remainder	0.1322	10	0.0132		

^{137}Cs takes place in the period from before the emergence of the ears until harvest). This observation is in reasonable agreement with that of the previous years and fits the hypothesis that the ^{137}Cs level in grain depends mainly upon the fall-out rate.

In Appendix C is shown a comparison between observed and predicted ^{90}Sr and ^{137}Cs levels in 1972.

The mean ratio between pCi ^{137}Cs/kg rye and pCi ^{90}Sr/kg rye was 1.29, while the ^{137}Cs/^{90}Sr ratio for barley, wheat, and oats was 0.67, 0.57 and 0.43 respectively. This is in agreement with earlier observations and with the theory that, contrary to the other cereals for which the soil uptake of ^{90}Sr now plays a dominant role, rye is mainly directly contaminated.

Table 5.3.7 shows the stable strontium content in grain in relation to the calcium content, and table 5.3.8 is an analysis of variance of the figures. As previously[1], wheat contained more stable strontium per g Ca than the other species, and the stations in Jutland showed generally higher figures than the eastern locations.

5.4. Strontium-90 and Caesium-137 in Bread from the Entire Country

In 1972, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected all over the country in June, but as in 1971 not in December. The samples were combined into eight zone samples and a sample from Copenhagen, and ^{90}Sr and ^{137}Cs were determined. The ^{137}Cs determinations were carried out on dried samples of rye bread and on the ash of white bread by Y-spectroscopy.

Tables 5.4.1 and 5.4.2 show the results. It is assumed that 1 kg flour yields approx. 1.35 kg bread[11] and that wheat flour of 75% extraction contains 20% of the ^{90}Sr and 50% of the ^{137}Cs found in wheat grain[1], while rye flour is 100% extraction hence we can compare the 1972 bread levels with the 1971 grain levels (cf. table 5.4.3).

Table 5.4.3 shows that the ^{90}Sr and ^{137}Cs levels in bread were generally lower than those in grain according to the above-mentioned model, ^{90}Sr in white bread being an exception.

Table 5.4.1

Sr-90 in Danish bread in June 1972

Zone		White bread		Rye bread	
		pCi/kg	S.U.	pCi/kg	S.U.
I:	N. Jutland	10.1±1.2	5.4±0.4	35±2	11.0±1.2
II:	E. Jutland	9.1±0.1	4.8±0.0	49±2	17.2±0.7
III:	W. Jutland	7.4±0.9	4.2±0.4	36±1	11.7±0.3
IV:	S. Jutland	8.4±0.3	5.5±0.2	35±7	11.1±2.0
V:	Funen	8.1±1.0	3.7±0.4	40±1	12.7±1.4
VI:	Zealand	8.3±0.0	3.8±0.1	31±1	11.0±0.7
VII:	Lolland-Falster	7.0±0.7	3.6±0.3	27±2	9.8±0.6
VIII:	Bornholm	7.7±1.6	3.4±0.7	25±1	7.8±0.3
Mean		8.3	4.3	35	11.5
Copenhagen		7.4±1.7	3.0±0.7	25±2	10.1±0.7
Population-weighted mean		8.2	4.0	34	11.9
Relative error due to sampling and analyses		15%	12%	12%	13%

Table 5.4.2

Cs-137 in Danish bread in June 1972

Zone		White bread		Rye bread	
		pCi/kg	M.U.	pCi/kg	M.U.
I:	N. Jutland	22.7	15.4	57	18
II:	E. Jutland	14.4±0.3	10.7±1.8	69	20
III:	W. Jutland	22.6	14.3	54	14
IV:	S. Jutland	20.3±0.7	15.0±1.4	48	15
V:	Funen	23.2	16.5	86	25
VI:	Zealand	25.3	15.5	68	21
VII:	Lolland-Falster	6.6 B	5.3 B	50	16
VIII:	Bornholm	12.3±3.8 A	9.0±2.4 A	67	18
Mean		18.4	12.7	62	18
Copenhagen		12.4	9.1	50	16
Population-weighted mean		18.4	12.6	61	18

A: Relative S.D.: 20-33%

B: Relative S.D.: >33%

Table 5.4.3

A comparison Sr-90 and Cs-137 levels in bread and grain in 1972

Nuclide	Species	Bread activity in June 1972 calculated as grain in pCi/kg (cf. text)	Activity in grain from harvest 1971[1]) pCi/kg	"Bread"/grain ratio
Sr-90	Wheat	55	48	1.15
	Rye	46	62	0.74
Cs-137	Wheat	49	66	0.74
	Rye	81	125	0.65

5.5. Strontium-90 and Caesium-137 in Potatoes from the Entire Country

The samples of potatoes were collected in September from ten of the State experimental farms (cf. fig. 4.1.1) and analysed for ^{90}Sr and ^{137}Cs (γ-spectroscopy of bulked samples of the ash).

Table 5.5.1 shows the ^{90}Sr and ^{137}Cs contents in potatoes. The mean contents for the country were 2.9 pCi ^{90}Sr/kg or 50 S.U. and 4.9 pCi ^{137}Cs/kg or 1.0 M.U.

The mean of the $^{137}Cs/^{90}Sr$ ratios (pCi/kg figures) was 1.7 (in 1971: 3.1, in 1970: 3.8, in 1969: 1.8, in 1968: 2.6, in 1967: 2.1, in 1966: 2.6, in 1965: 6, and in 1964: 9).

Table 5.5.1

Sr-90 and Cs-137 in Danish potatoes in 1972

	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.
Tylstrup	3.2±0.1	51±13		
Studsgård	4.0±0.1	64±7		
Ødum	2.0±0.0	37±4	6.9	1.5
Askov	2.7±0.1	46±2		
St. Jyndevad	2.7±0.2	7 ±7		
Blangstedgård	2.6±0.4	34±6		
Tystofte	4.4±0.2	57±7		
Ledreborg	2.3±0.0	33±2	2.8	0.5
Abed	2.3±0.2	35±0.9		
Mean	2.9	50	4.9	1.0

The error terms are the S.E. of the mean of double determinations.

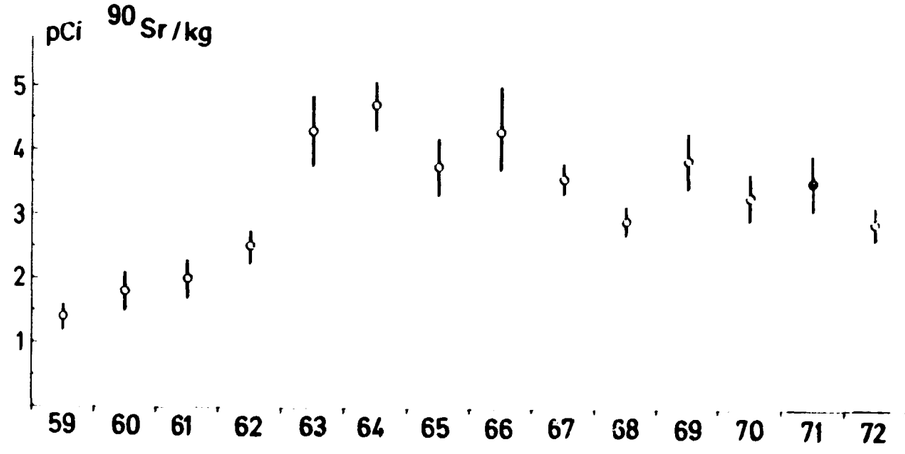

Fig. 5.5.1. Strontium-90 levels in Danish potatoes, 1959-72 (1 S.E. indicated).

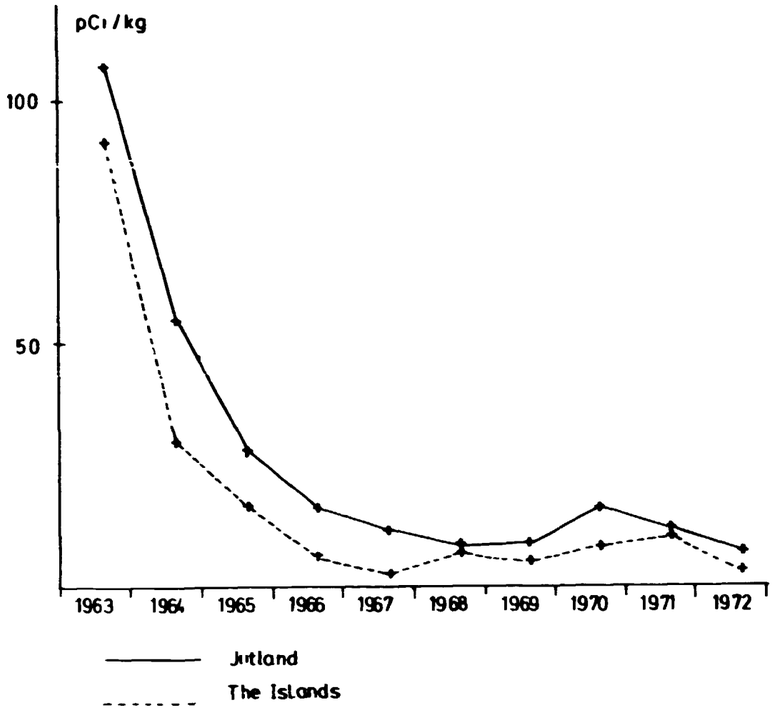

Fig. 5.5.2. Caesium-137 in potatoes from Jutland and the Islands, 1963-72.

5.6. Strontium-90 and Caesium-137 in Vegetables and Fruits from the Entire Country

In 1972 as in previous years, vegetables and fruits were collected in September and December from eight greater provincial towns, one in each of the eight zones, and from Copenhagen.

Carrots and onions were collected in September, cabbages and apples in December, and a few samples of beans and gooseberries were collected in June-July.

The γ-measurements were performed on bulked ash samples representing the entire country (cf. table 5.6.4). Tables 5.6.1 - 5.6.3 show the results and the analysis of variance of the ^{90}Sr determinations.

The variations between species were highly significant. The highest ^{90}Sr levels (pCi/kg) were found in onion, and carrot, the lowest in apple. The variation between locations was also significant. Jutland showed as a whole higher levels than the Islands.

Fig. 5.6.1 shows the country wide mean pCi ^{90}Sr/g Ca levels in cabbage (white and red) and in carrots collected since 1961. The cabbage levels

Table 5.6.1

Sr-90 in vegetables and fruits in 1972

Zone		Cabbage		Carrot		Onion		Apple		Beans		Gooseberry	
		pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.
I:	N-Jutland	12.9±0.9	30.3±6.0	18.5	49.2	20.3	91	1.4	43.2	19.6	45.6	7.9	35.8
II:	E-Jutland	13.4±5.6	32.2±1.8	30.8	116.3	16.4	92	1.5	31.4	16.0	31.6	12.0	49.5
III:	W-Jutland	17.6±6.0	37.3±12.3	42.0	124.9	15.9	87	1.1	14.8	19.6	43.5	15.6	31.6
IV:	S-Jutland	11.1±2.0	23.9±0.5	14.2	38.1	24.9	97	1.3	28.8	13.8	34.8	17.1	53.5
V:	Funen	9.5±1.8	18.0±2.4	5.9	17.6	11.7	53	0.8	18.3	(8.4)	(17.8)	7.2	21.7
VI:	Zealand	4.4±1.6	8.8±3.5	7.1	21.9	14.7	53	1.6	29.9	(7.4)	(16.3)	6.0	31.3
VII:	Lolland-Falster	5.0±0.4	13.4±0.3	9.0	24.1	10.3	34	1.1	23.6	(7.8)	(18.4)	9.6	41.1
VIII:	Bornholm	8.2±2.0	15.3±3.0	20.0	32.2	10.8	35	3.4	64.7	13.5	25.0	18.5	32.3
Mean		10.3	22.4	18.6	53.0	15.6	62.8	1.5	31.8	13.3	29.1	11.7	37.1
Copenhagen		3.3	7.0	8.8	24.3	7.5	25	1.4	36.4	4.7	9.2	7.7	38.6
Population-weighted mean		9.0	19.9	18.0	55.6	13.9	55	1.4	30.4	11.4	24.6	9.8	37.4

Values in brackets were calculated from VAR 3
Cabbage were collected along with the total diet in December in both A & B towns.
The error term for cabbage thus include sampling as well as analytical error.

Table 5.6.2

Analysis of variance of ln pCi Sr-90/kg in vegetables and fruits in 1972 (from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	34.2258	5	6.8452	45.76	>99.95%
Betw. locations	7.5226	8	0.9403	6.29	>99.95%
Loc. x species	5.5363	37	0.1496	1.00	-
Remainder	1.2023	8	0.1503		

Table 5.6.3

Analysis of variance of ln S.U. in vegetables and fruits in 1972 (from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	8.9655	5	1.7931	8.83	>99.95%
Betw. locations	6.3891	8	0.7986	3.93	>99.5%
Loc. x species	7.5114	37	0.2030	1.01	-
Remainder	1.6006	8	0.2001		

Table 5.6.4

Cs-137 in vegetables and fruits in 1972

	Cabbage	Carrot	Onion	Apple	Beans	Gooseberry
pCi/kg	3.8±0.1	3.1	A 0.9	5.4	B 1.1	A 2.9
pCi/g K	1.5±0.0	1.4	A 0.4	3.5	B 0.3	A 1.6

A: relative S.D.: 20-33%

B: relative S.D.: >33%

The error term is the S.E. of the mean.

Table 5.6.5

Calculated Sr-90 and Cs-137 mean levels in vegetables in 1972

Daily intake in g	Species	pCi Sr-90 per kg	S.U.	pCi Cs-137 per kg	M.U.
50	Leafy vegetables (cabbage)	9.0	19.9	3.8	1.5
30	Root vegetables (carrot, onion)	16.0	55.3	2.0	0.9
40	(Pea) and bean	11.4	24.6	1.1	0.3
120	Vegetable total	11.6	30.3	2.4	1.0

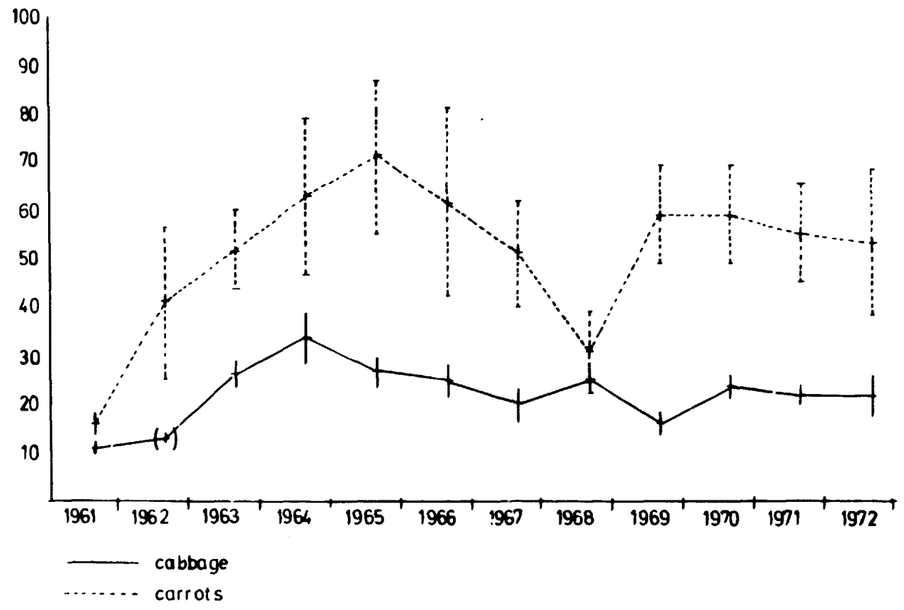

Fig. 5.6.1. Strontium-90 in Danish cabbage and carrots, 1961-72.

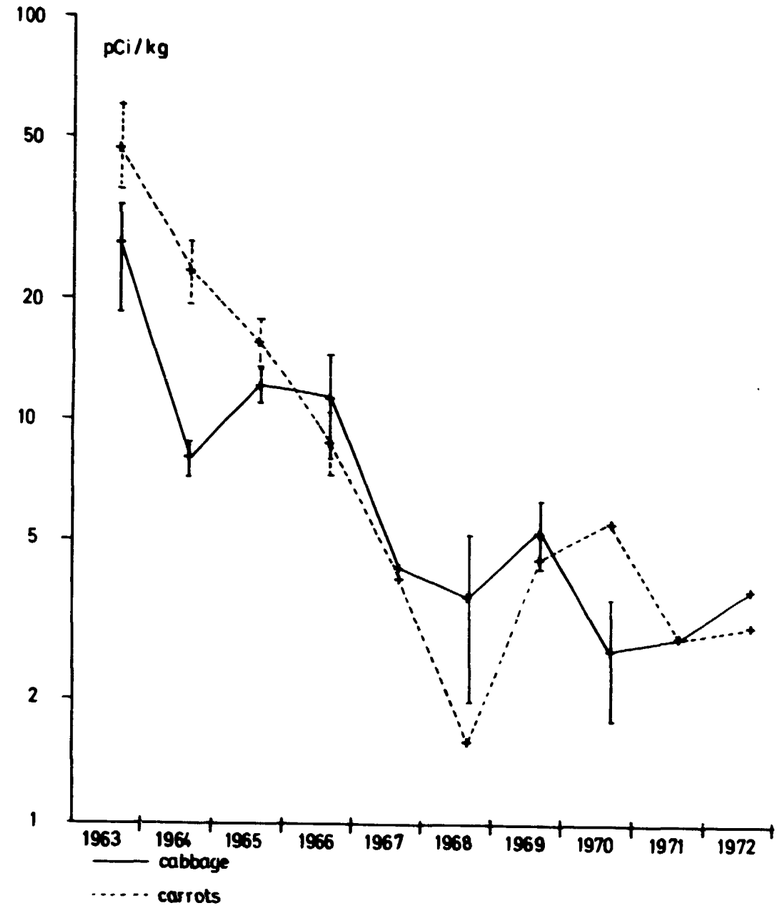

Fig. 5.6.2. Caesium-137 in Danish cabbage and carrots, 1963-72.

have since 1966 varied around 20 pCi ^{90}Sr/g Ca and the carrot levels have been between 50 and 60 pCi ^{90}Sr/g Ca, except in 1968 when the mean level was only 30 pCi ^{90}Sr/g Ca. We have no explanation for this low value in 1968 (the S.E. of the mean was not different from those years just before and after 1968). Caesium-137 also showed a minimum for carrots in 1968, and as the ^{90}Sr and ^{137}Cs determinations are independent, it is unlikely that the low values should arise from analytical errors. (Fig. 5.6.2).

The ^{90}Sr levels in cabbage and carrots depend primarily on the ^{90}Sr activity in the soil, during the last years approx. 95% of the ^{90}Sr came from the accumulated ^{90}Sr in the soil. The rather constant levels since 1966 are in accordance with the nearly constant soil levels (cf. 4.2), but do not fit the theory of a rapid decrease (effective half life~ 4 years) in the availability of the ^{90}Sr in the soil for root uptake, as proposed in Risø Report No. 265, Appendix C[1] (cf. also Appendix C in this report).

Table 5.6.5 shows a calculation of the mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1972. The levels are the population-weighted means calculated in tables 5.6.1 - 5.6.4.

The 1972 levels in Danish fruit were calculated from apple and from gooseberry. Apples got a weight factor of 85 and gooseberries one of 15, and the mean levels in Danish fruit were thus 2.7 pCi ^{90}Sr/kg and 5 ^{137}Cs/kg.

The 1972 ^{90}Sr levels in vegetables and fruits were a little higher and the ^{137}Cs levels somewhat lower than the 1971 levels.

5.7. Strontium-90 and Caesium-137 in Total Diet from the Entire Country

In 1972 total-food samples representing an average Danish diet according to E. Hoff-Jørgensen (cf. Appendix B in Risø Report No. 63[1]) were collected according to the principles followed in 1961-1971. As previously two groups of towns (A and B, cf. figs. 5.2.1 and 5.2.2) supplied the samples.

Tables 5.7.1 and 5.7.2 show the results. As in previous years, the variation between locations was significant. The S.U. levels in the total diet were approx. 30% higher in Jutland than in eastern Denmark.

Fig. 5.7.1 shows the zone mean levels (not population-weighted) of S.U. in total diet since May 1961. Fig. 5.7.2 shows the daily ^{137}Cs intake since June 1963.

The 1972 ^{90}Sr levels in total diet were approx. 10% higher than the 1971 levels, while the ^{137}Cs levels were approx. 25% lower than the 1971 ones.

From the total-diet sampling it is possible to estimate the mean levels of ^{90}Sr and ^{137}Cs in the Danish diet in 1972. For the period January-April 1971 the ^{90}Sr level in the total diet is assumed to have been equal to that measured in December 1971, Risø Report No. 265[1]. For the period May-September we assume the level to have corresponded to that measured in June 1972. The December 1972 figure is taken to represent the last three months of the year. The population-weighted mean of ^{90}Sr in total-diet samples was 7.0 pCi ^{90}Sr/g Ca in December 1971. Hence the mean content in the total diet in 1972 was 7.8 pCi ^{90}Sr/g Ca or 13.7 pCi ^{90}Sr/day.

In a similar way the ^{137}Cs content in the Danish diet in 1972 was estimated to be 30 pCi ^{137}Cs/day or 8.8 pCi ^{137}Cs/g K (cf. also Appendix C).

Table 5.7.1

Sr-90 and Cs-137 in Danish total diet collected in June 1972

Zone		pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	pCi Cs-137/g K	pCi Cs-137/day
I:	N. Jutland	9.1±1.3	15.8±3.1	1.78±0.04	8.5±0.7	29.8±1.0
II.	E. Jutland	10.1±2.8	18.2±5.8	1.77±0.09	7.6±2.2	26.9±5.8
III:	W. Jutland	9.8±1.0	16.6±1.8	1.71±0.00	7.8±0.4	29.8±1.0
IV:	S. Jutland	11.2	20.5	1.83	8.8±2.0	31.4±4.1
V:	Funen	9.9±1.2	18.2±3.4	1.83±0.11	10.3±0.5	34.0±0.6
VI:	Zealand	8.0±0.2	14.4±0.2	1.85±0.04	7.4±0.4	28.2±1.3
VII:	Lolland-Falster	7.5±0.6	13.1±0.0	1.74±0.12	9.3±2.0	35.2±5.1
VIII:	Bornholm	8.1±0.3	14.6±0.6	1.80±0.02	6.9±0.3	25.9±0.3
Mean		8.8	16.4	1.79	8.3	30.2
Copenhagen		7.1±0.41	13.4±0.7	1.90±0.02	7.4	25.5
Population-weighted mean		8.8	15.9	1.83	8.0	28.5
Relative error due to sampling and analysis		23%	26%	6%	23%	15%

Table 5.7.2

Sr-90 and Cs-137 in Danish total diet collected in December 1972

Zone		pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	pCi Cs-137/g K	pCi Cs-137/day
I:	N. Jutland	8.1±0.3	12.9±0.5	1.61±0.0	5.4±1.6	19.4±5.7
II:	E. Jutland	8.1±0.1	12.7±0.1	1.58±0.0	5.7±0.0	21.2±0.0
III:	W. Jutland	8.9±0.0	14.5±0.5	1.62±0.1	5.3±1.6	20.1±5.0
IV:	S. Jutland	8.8±0.6	14.0±0.8	1.55±0.1	5.6±0.9	22.1±3.9
V:	Funen	6.3±0.6	9.5±0.0	1.53±0.2	8.4±4.5	24.7±9.5
VI:	Zealand	6.7±0.5	10.8±1.3	1.61±0.1	5.6±1.0	20.1±4.1
VII:	Lolland-Falster	5.9±0.4	9.1±0.3	1.55±0.1	7.4±1.2	28.4±4.2
VIII:	Bornholm	7.0±0.3	12.0±0.0	1.73±0.1	6.1±1.2	20.5±4.6
Mean		7.5	11.9	1.60	6.2	22.1
Copenhagen		6.8±0.6	12.0±1.4	1.79±0.0	7.4	25.1
Population-weighted mean		7.5	12.2	1.65	6.4	22.4
Relative error due to sampling and analysis		8%	7%	9%	44%	33%

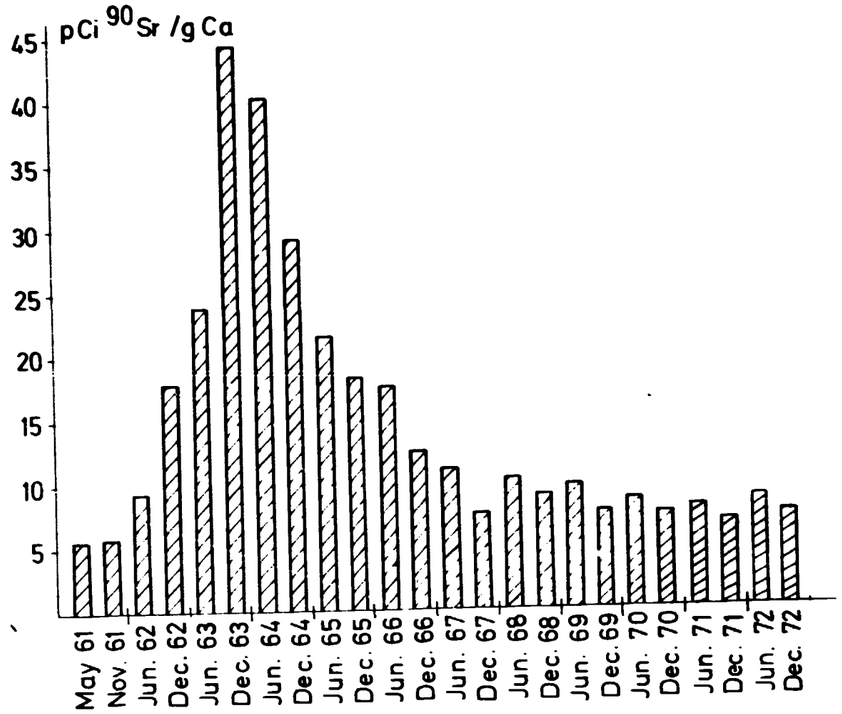

Fig. 5.7.1. pCi ^{90}Sr/g Ca in Danish total diet, 1961-72.

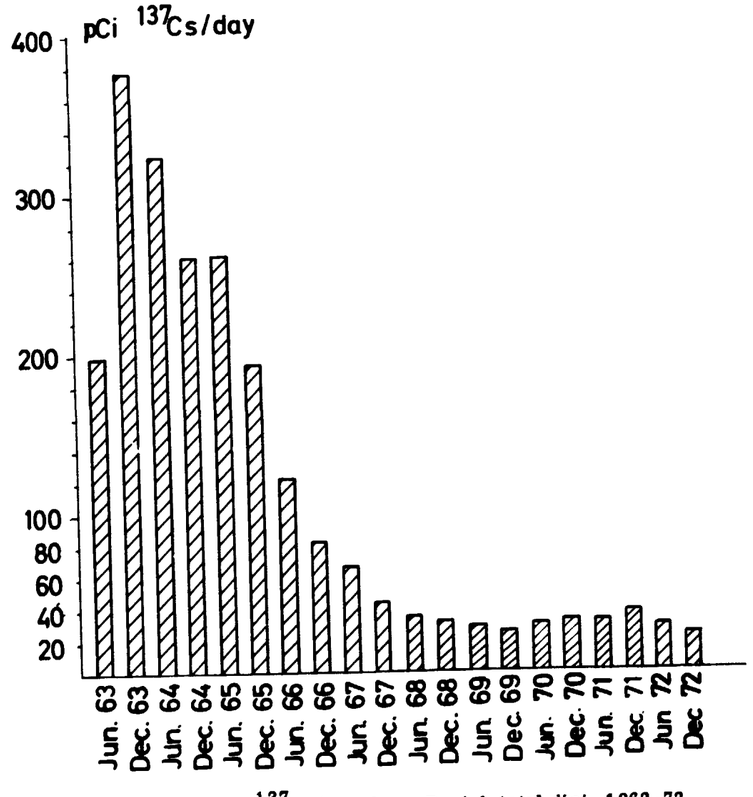

Fig. 5.7.2. pCi ^{137}Cs/day from Danish total diet, 1963-72.

5.8. Strontium-90 and Caesium-137 in Miscellaneous Foodstuffs

5.8.1. Strontium-90 and Caesium-137 in Meat

Pork and beef samples were collected in Copenhagen in three big shops in March, June, September, and December. Table 5.8.1 shows the results. Figs. 5.8.1.1 and 5.8.1.2 show a comparison between milk and meat levels. The ratio (pCi ^{90}Sr/kg meat)/(pCi ^{90}Sr/l milk) was 0.18 (S.E. 0.02), and the corresponding ratio for ^{137}Cs was 5.1 (S.E. 0.3) for the period 1962-1972. (In these calculations meat consisted of 2/3 pork and 1/3 beef) (cf. also Appendix C).

Table 5.8.1

Sr-90 and Cs-137 in pork and beef from Copenhagen in 1972

Species	Unit	March	June	Sep.	Dec.	Mean
Pork	pCi Sr-90/kg	A 0.72	A 1.00	B 0.51	B 0.30	0.63
	pCi Sr-90/g Ca	5.9	9.7	4.9	2.0	5.6
	pCi Cs-137/kg	57	49	59	46	53
	pCi Cs-137/g K	22	13	21	18	19
Beef	pCi Sr-90/kg	B 0.93	1.11	A 0.97	A 0.68	0.92
	pCi Sr-90/g Ca	8.3	9.3	9.7	8.2	8.9
	pCi Cs-137/kg	51	A24	45	30	38
	pCi Cs-137/g K	15	7.5	12	9.1	10.9

A: relative S.D.: 20-33%

B: relative S.D.: > 33%

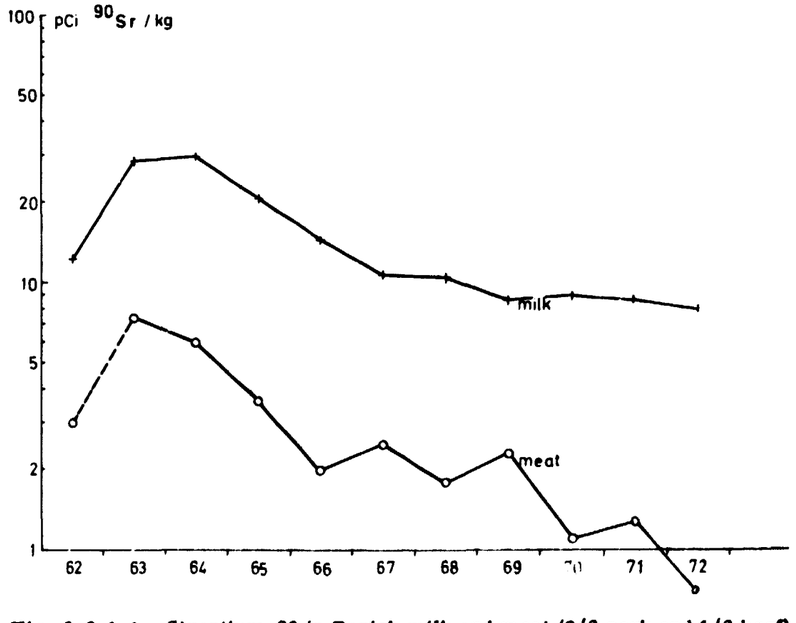

Fig. 5.8.1.1. Strontium-90 in Danish milk and meat (2/3 pork and 1/3 beef), 1962-72.

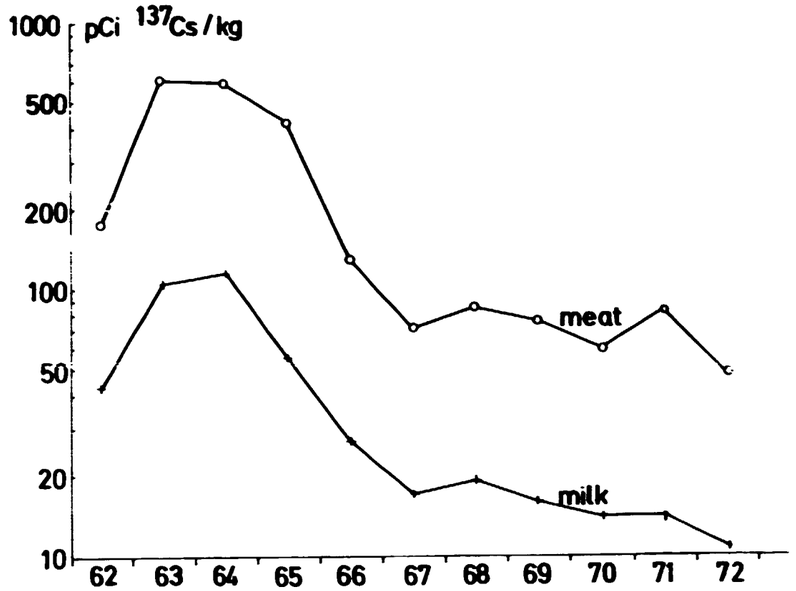

Fig. 5.8.1.2. Caesium-137 in Danish milk and meat (2/3 pork and 1/3 beef), 1962-72.

5.8.2. Strontium-90 and Caesium-137 in Fish

Fish samples were collected around Zealand in June-December. Tables 5.8.2.1 and 5.8.2.2 show the results. The mean levels were 2.3 pCi ^{90}Sr/kg meat (1 SE: 0.5) and 78 pCi ^{137}Cs/kg meat (1 SE: 29). The levels were in agreement with previous years concentrations cf. 5.8.2. Tables 5.8.2.1 and 5.8.2.2 show a number of 1971 samples; the mean levels of these samples were 1.2 pCi ^{90}Sr/kg meat (1 SE: 0.1) and 45 pCi ^{137}Cs/kg meat (1 SE: 7). The levels were not significantly different from those reported in Risø Report No. 265 from 1971.

Fig. 5.8.2 shows a correlation between ^{90}Sr in surface sea water and ^{90}Sr in fish meat. The ^{90}Sr concentration in fish was approx. twice that in sea water.

The figure further shows that the ^{137}Cs concentration in fish was approx. a hundred times the ^{90}Sr level in sea water. The $^{137}Cs/^{90}Sr$ ratio in sea water is 1.6 (1 SE:0.1)[16], hence the concentration factor for fish from sea water becomes 65.

Table 5.8.2.1

Sr-90 and Cs-137 in cod collected in 1971 and 1972 in Danish waters
(the samples from 1971 have not been published earlier)

Cod		Month	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
* 54°55'N	meat	June	1.83	1.83	107	21
12°25'E	bone	-	-	1.23	-	-
* Hundested	meat	June	A 0.87	A 1.66	52	15
	bone	-	-	-	-	-
* Kerteminde	meat	June	B 0.66	B 1.00	51	14
bay	bone	-	-	0.81	-	-
Barsebäck	meat	June	B 0.72	B 0.66	119	30
I	bone	-	-	0.64	-	-
Barsebäck	meat	June	B 3.82	B 6.45	171	43
II	bone	-	-	0.39	-	-
Barsebäck	meat	June	A 2.26	A 2.77	60	16
III	bone	-	-	0.71	-	-
Mean ±1 S.E.	meat		1.69±0.50	2.50±0.82	93±20	23±5
Mean ±1 S.E.	bone		-	0.76±0.14	-	-

* Collected in 1971.

A: relative S.D.: 20-33%

B: relative S.D.: >33%

Table 5.8.2.2

Sr-90 and Cs-137 in fish (apart from cod) collected in 1971 and 1972 in Danish waters

Species		Month	pCi Sr-90/kg	pCi Sr-90/g Ca	pCi Cs-137/kg	pCi Cs-137/g K
x Dab Barsebäck Trawlestation C	meat bone	Oct.	1.43 -	0.77 0.52	28 -	6 -
x Dab 55°52'5"N 12°39'E	meat bone	June	B 1.38 -	B 0.57 0.64	39 -	10 -
x Dab Kerteminde bay	meat bone	June -	1.57 -	0.70 0.41	27 -	8 -
x Plaice Barsebäck Trawlestation C	meat bone	Oct.	A 0.96 -	A 1.36 0.43	35 -	8 -
Flatfish Barsebäck	meat bone	June -	2.51 -	1.38 0.39	20 -	7 -
Plaice Barsebäck	meat bone	June -	2.17 -	3.19 0.63	22 -	8 -
x Garfish Kalundborg	meat bone	June -	- -	- -	71 -	15 -
x Mackerel Gilleleje	meat bone	June -	B 0.81 -	B 1.62 A 0.50	36 -	10 -
x Mackerel Skagen	meat bone	June -	B 0.95 -	B 6.78 B 0.53	38 -	9 -
x Small fishes Kerteminde bay	total	June	-	-	20	6
x Herring Hundested	meat bone	June -	- -	- -	41 -	9 -
Mean ± SD	meat		1.47±0.21	2.04±0.73	36±5	9±1
Mean ± SD	bone		-	0.51±0.03	-	-
Mean ± SD	total		-	-	20±0	6±0

x: Collected in 1971

A: relative S.D.: 20-33%

B: relative S.D.: >33%

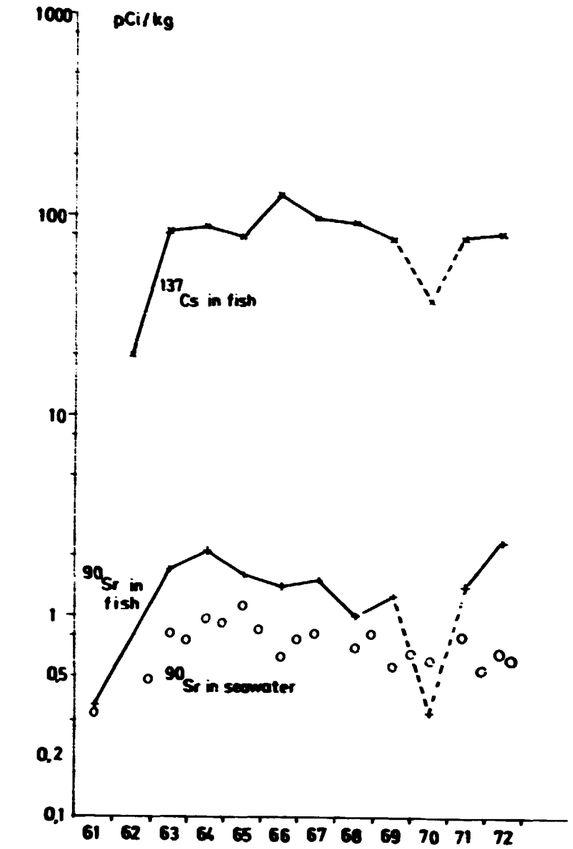

Fig. 5.8.2. Strontium-90 and ^{137}Cs in Danish fish compared with ^{90}Sr in sea water, 1961-72 (cf. remarks in Risø Report No. 265[1], p. 64, concerning the 1970 levels).

5.8.3. Strontium-90 in Drinking Water

Along with the total-diet samples, 10 l of drinking water was collected in June in each of the 48 towns (cf. figs. 5.2.1 and 5.2.2). The 10 l samples were bulked into eight zone samples, each comprising 60 l of water. The samples were analysed, by the method used for ground water, for ^{90}Sr, stable strontium, and calcium.

Table 5.8.3 shows the results.

Table 5.8.3

Sr-90 in Danish drinking water in June 1972

Zone		pCi Sr-90/l	g Ca/l	mg Sr/g Ca
I:	N-Jutland	0.029	0.085	6.5
II:	E-Jutland	0.032	0.078	9.1
III:	W-Jutland	0.011	0.059	3.9
IV:	S-Jutland	0.004 A	0.075	3.4
V:	Funen	0.010 A	0.130	9.3
VI:	Zealand	0.015 A	0.107	19.8
VII:	Lolland-Falster	0.015 B	0.114	24.0
VIII:	Bornholm	0.018 B	0.066	6.8
Mean		0.017	0.089	10.4
Copenhagen		0.087	0.135	9.7
Median of zones		0.015	0.082	7.9
A: relative S.D.: 20-33%				
B: relative S.D.: > 33%				

5.8.4. Strontium-90 and Caesium-137 in Various Foodstuffs

In December a number of imported and other foods were provided from shops in Copenhagen. Table 5.8.4 shows the results.

Table 5.8.4

Sr-90 and Cs-137 in various foods collected in Copenhagen in December 1972

Sample	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.	nSr mg/g Ca
Coffee	10.0	12.9	A 36	A 2	17.6
Tea	50.8	33.2	247	16	21.6
Orange	5.2	14.2	-	-	6.6
Lemon	11.1	39.6	B 1.8	B 0.9	7.5
Banana	1.6	29.6	B 2.2	B 0.6	4.8
Hazelnut	64.4	52.8	66	8	4.3
Grape	2.6	16.2	B 1.1	B 0.5	12.3
Raisin	7.3	12.2	B 6.4	B 0.8	5.4
Oatmeal	27.3	7.5	47	18	2.2
Cheese	45.0	6.5	B 5	B 7	0.7
Chicken meat	0.6	3.2	A 9	A 3	1.1
Chicken bone	-	2.1	-	-	1.6
Chicken pluck	1.0	14.0	A 19	A 6	2.9
A: relative S.D.:20-33%					
B: relative S.D.:>33%					

5.9. Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Human Diet in Denmark in 1972

5.9.1. The Annual Quantities

The annual quantities are calculated by multiplication of the daily quantities (as stated by E. Hoff-Jørgensen, cf. Risø Report No. 63, table B[1]) by 365.

5.9.2. Milk and Cream

The ^{90}Sr and ^{137}Cs contents per kg milk were calculated from the annual mean values for dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg ~ 1 l milk, containing approx. 1.2 g Ca and 1.66 g K. Hence the mean contents in milk were 7.9 pCi ^{90}Sr/kg and 11 pCi ^{137}Cs/kg.

5.9.3. Cheese

1 kg of cheese contains approx. 8.5 g Ca and 1.2 g K. The ^{90}Sr and ^{137}Cs contents in cheese were calculated from these figures and from the S.U. and M.U. levels in dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg of cheese appeared to contain 56 pCi ^{90}Sr and 8 pCi ^{137}Cs.

5.9.4. Grain Products

Tables 5.9.1 and 5.9.2 show the estimates of ^{90}Sr and ^{137}Cs respectively in grain products consumed in 1972. From these tables the activity levels in grain products were estimated at 27 pCi ^{90}Sr/kg and 57 pCi ^{137}Cs/kg.

Table 5.9.1

Estimate of the Sr-90 content in grain products consumed per capita in 1972

Type	Fraction from harvest 1971			Fraction from harvest 1972			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	62	1358	7.3	29	212	1570
Wheat flour (75% extraction)	32.9	9.6	316	10.9	6.6	72	388
Grits	5.5	30.4	167	1.8	23.2	42	209
Total	60.3	30.5	1841	20.0	16.3	326	2167

Table 5.9.2

Estimate of the Cs-137 content in grain products consumed per capita in 1972

Type	Fraction from harvest 1971			Fraction from harvest 1972			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	125	2738	7.3	37	270	3008
Wheat flour (75% extraction)	32.9	33	1086	10.9	9.4	102	1188
Grits	5.5	62	341	1.8	18.5	33	374
Total	60.3	69	4165	20.0	20	405	4570

5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 2.9 pCi ^{90}Sr/kg and 4.9 pCi ^{137}Cs/kg.

5.9.6. Vegetables

Table 5.6.5 shows the calculation of ^{90}Sr and ^{137}Cs in Danish vegetables consumed in 1972. The mean contents were 11.6 pCi ^{90}Sr/kg and 2.4 pCi ^{137}Cs/kg.

5.9.7. Fruit

The levels in imported fruit in 1972 are assumed to be equal to the mean levels found in lemons, oranges, and bananas collected in Copenhagen in 1972, i.e. 3.4 pCi ^{90}Sr/kg and 1.3 pCi ^{137}Cs/kg (cf. 5.8.4). The mean levels in Danish fruit in 1972 were 2.7 pCi ^{90}Sr/kg and 5 pCi ^{137}Cs/kg (cf. 5.6). The daily mean consumption of fruit consisted of 100 g of Danish and 40 g of foreign origin. Hence the mean contents in fruit were 2.9 pCi ^{90}Sr/kg and 4 pCi ^{137}Cs/kg.

5.9.8. Meat

From table 5.8.1 the annual mean values of ^{90}Sr and ^{137}Cs in meat were calculated: 0.7 pCi ^{90}Sr/kg and 48 pCi ^{137}Cs/kg. (Danish meat consists of 2/3 pork and 1/3 beef).

5.9.9. Fish

The ^{90}Sr and ^{137}Cs contents in fish are given in 5.8.2, i.e. 2.3 pCi ^{90}Sr/kg and 78 pCi ^{137}Cs/kg.

5.9.10. Eggs

The activity contents in eggs were estimated from last years measurements[1]. The levels were 2 pCi ^{90}Sr/kg and 4 pCi ^{137}Cs/kg.

5.9.11. Coffee and Tea

A third of the total consumption consists of tea and two thirds of coffee. The mean contents were consequently (cf. 5.8.4) 23.6 pCi ^{90}Sr/kg and 106 pCi ^{137}Cs/kg.

5.9.12. Drinking Water

The ^{90}Sr level found in drinking water collected in June (cf. table 5.8.3) was used as the country mean for drinking water, i.e. 0.02 pCi ^{90}Sr/l. The ^{137}Cs content in drinking water is assumed to be negligible.

5.9.13. Discussion

Tables 5.9.3 and 5.9.4 show the estimates of ^{90}Sr and ^{137}Cs in the Danish diet in 1972. The figures should be compared with the levels calculated from the total-diet samples (cf. 5.7). The ^{90}Sr estimates obtained by the two methods were 8.2 S.U. and 7.8 S.U. respectively, and the ^{137}Cs estimates were 31 pCi ^{137}Cs/day and 30 pCi ^{137}Cs/day.

Table 5.9.3

Estimate of the mean content of Sr-90 in the human diet in Denmark in 1972

Type of food	Annual quantity in kg	pCi Sr-90 per kg	Total pCi Sr-90	Percentage of total pCi Sr-90 in food
Milk and cream	164.0	7.9	1296	25.6
Cheese	9.1	56.0	510	10.1
Grain products	80.3	27.0	2167	42.8
Potatoes	73.0	2.9	212	4.2
Vegetables	43.8	11.6	508	10.0
Fruit	51.1	2.9	148	2.9
Meat	54.7	0.7	38	0.7
Eggs	10.9	2.0	22	0.4
Fish	10.9	2.3	25	0.5
Coffee and tea	5.5	23.6	130	2.6
Drinking water	548	0.02	11	0.2
Total			5067	

The mean calcium intake was estimated at 620 g (approx. 200-250 g Creta praeparata). Hence the Sr-90/Ca ratio in the total diet was 8.2 S.U. in 1972.

Table 5.9.4

Estimate of the mean content of Cs-137 in the human diet in Denmark in 1972

Type of food	Annual quantity in kg	pCi Cs-137 per kg	Total pCi Cs-137	Percentage of total pCi Cs-137 in food
Milk and cream	164.0	11	1804	16.1
Cheese	9.1	8	73	0.7
Grain products	80.3	57	4570	40.7
Potatoes	73.0	4.9	358	3.2
Vegetables	43.8	2.4	105	0.9
Fruit	51.1	4	204	1.8
Meat	54.7	48	2626	23.4
Eggs	10.9	4	44	0.4
Fish	10.9	78	850	7.6
Coffee and tea	5.5	106	583	5.2
Drinking water	548	0	0	0
Total			11217	

As the approximate intake of potassium was 1365 g, the pCi Cs-137/g K ratio was approx. 8.2. The daily mean intake in 1972 was 31 pCi Cs-137 per capita.

The relative contribution of ^{90}Sr from milk products decreased from approx. 40% in 1971 to 36% in 1972, whereas that from grain products increased from 34 to 43%. The contribution from potatoes, other vegetables, and fruit was 17%, i.e. a little lower than in 1971. The relative contribution of ^{137}Cs in the total diet changed as follows from 1971 to 1972: Milk products were unchanged 17%, grain products increased from 32 to 41%, and meat decreased from 32 to 23%.

6. STRONTIUM-90 AND CAESIUM-137 IN MAN IN 1972

6.1. Strontium-90 in Human Bone

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1972. As in the total-food survey (cf. 5.7), the country was divided into eight zones. The samples were divided into five age groups: new-born (⟨1 month), infants (1 month-4 years), children and teen-agers (5 - 19 years), adults (≤29 years) and adults (⟩29 years).

Tables 6.1.1 - 6.1.5 show the results for the five groups.

The levels were generally lower in 1972 than in 1971 for all age groups except new-born. The highest levels in vertebrae were found in the infant, the lowest among adults (cf. fig. 6.1). Adults between 20 and 29 years showed as previously higher levels than adults of more than 29 years.

As in previous years[1], the mean OR: S.U. (new-borns' bone)/S.U. (mothers' diet during pregnancy) was calculated from tables 6.1.1, 5.7.1, and 5.7.2 and Risø Report No. 245, tables 5.7.1 and 5.7.2[1]. For the years 1963-71 we found a mean OR value of 0.108 ± 0.008(1 SE), but in 1972 the observed ratio was 0.23 ± 0.05. We have no explanation for this probably significant greater OR in 1972.

Table 6.1.1

Sr-90 in bone from new-born children (< 1 month old) in 1972

Zone	Age in days	Month of death	Sex	pCi Sr-90/g Ca
I	1	3	M	A 2.03
I	17	1	F	2.55
II	2	3	F	3.06
II	7	1	F	A 0.47
III	1	5	F	2.09
VI	0	8	F	1.16

A: relative S.D.: 20-33%

B: relative S.D.: >33%

Table 6.1.2

Sr-90 in bone from infants (≤ 4 years old) in 1972

Zone	Age in years and months	Month of death	Sex	pCi Sr-90/g Ca
I	1 m	5	F	1.46
I	7 m	1	F	2.81
I	8 m	4	F	2.02
II	2 m	1	M	1.35
II	3 m	2	M	1.56
II	5 m	5	M	2.01
II	6 m	5	M	2.45
II	10 m	4	M	2.20
II	3.5 y	3	M	6.02
II	4 m	3	F	2.10
II	10 m	2	F	1.75
II	3 y	4	F	1.67
II	3.5 y	1	F	1.61
II	4 y	2	F	1.40
VI	3 m	2	M	2.01
VI	4 m	11	M	6.98
VI	4 m	2	M	3.49
VI	7 m	1	M	1.64
VI	4 m	9	F	2.71
VI	5 m	2	F	2.18
VI	1.7 y	1	F	2.15

Table 6.1.3

Sr-90 in bone from children and teen-agers (≤ 19 years) in 1972

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca
I	11	3	M	1.53
I	18	4	M	1.58
I	19	3	M	1.63
I	16	4	F	1.85
II	8	3	M	A 2.12
II	11	5	M	A 2.05
II	17	5	M	2.16
II	17	2	F	1.81
II	19	3	F	2.11
III	15	5	M	2.09
IV	7	3	F	1.68
VI	5	11	M	A 0.92
VI	5	11	M	A 1.11
VI	8	3	M	B 1.73
VI	14	2	M	A 1.62
VI	15	5	M	1.76
VI	16	11	M	2.38
VI	16	1	M	1.44
VI	17	9	M	1.60
VI	18	9	M	1.57
VI	18	1	M	A 1.19
VI	18	1	M	1.71
VI	19	10	M	1.10
VI	19	5	M	1.45
VI	19	4	M	A 1.24
VI	19	3	M	2.54
VI	6	2	F	3.32
VI	10	5	F	2.63
VI	14	11	F	A 1.13
VI	18	9	F	1.64

A: relative S.D.: 20-33%

B: relative S.D.: >33%

Table 6.1.4

Sr-90 in vertebrae from adults (≤ 29 years) in 1972

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca
I	22	3	M	A 1.61
VI	20	1	M	1.44
VI	21	11	M	1.61
VI	21	4	M	1.76
VI	22	3	M	2.09
VI	23	3	M	1.44
VI	24	3	M	1.60
VI	25	2	M	1.93
VI	27	2	M	A 1.56
A: relative S.D.: 20-33%.				

Table 6.1.5

Sr-90 in vertebrae from adults (> 29 years old) in 1972

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca
I	36	1	M	1.38
I	61	2	M	1.93
VI	33	3	M	1.63
VI	30	11	F	A 1.18
VII	44	10	M	A 1.03
A: relative S.D.: 20-33%				

Table 6.1.6

Sr-90 (pCi/g Ca) in human vertebrae collected in Denmark in 1972

Age group	Number of samples	Min.	Max.	Median	Mean
New-born (< 1 month)	6	0.47	3.06	2.06	1.89
Infants (≤ 4 years)	21	1.35	6.98	2.02	2.46
Children (≤ 19 years)	30	0.92	3.32	1.66	1.76
Adults (≤ 29 years)	9	1.44	2.09	1.61	1.67
Adults (≥ 30 years)	5	1.03	1.93	1.38	1.43

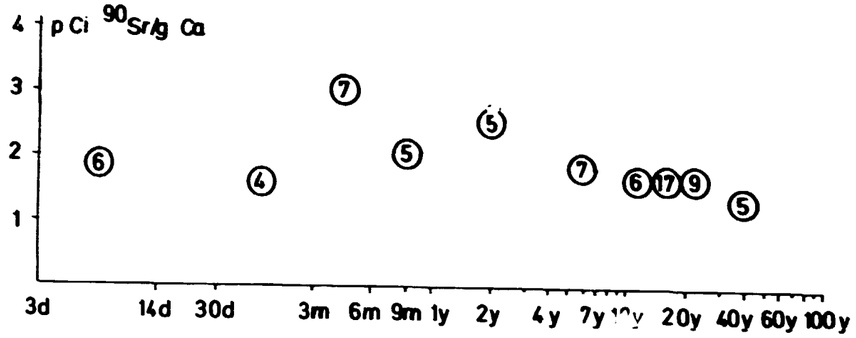

Fig. 6.1. Strontium-90 in human vertebrae in 1972 (the figures in the circles indicate the number of samples).

Table 6.1.7

Sr-90 in human bone in 1971

Zone	Age	Month of death	Sex	pCi Sr-90/g Ca
I	4 years	12	M	2.34
I	44 years	11	M	1.80
I	51 years	12	F	1.04
II	5 days	12	F	A 0.97
II	4 months	12	M	A 2.15
II	19 years	11	M	1.91
II	64 years	12	M	1.83
VI	5 years	9	M	A 2.30
VI	9 years	12	M	2.15
VI	18 years	9	M	2.42
VI	19 years	12	M	A 1.75
VI	16 years	12	F	2.25
VI	20 years	7	M	A 1.62
VI	20 years	9	M	1.80
VI	21 years	7	M	1.32
VI	28 years	11	M	A 1.84
VI	30 years	11	M	A 1.98
VI	38 years	6	M	1.81
VI	33 years	11	F	3.60
A: relative S.D.: 20-33%.				

6.2. Caesium-137 in the Human Body

In July 1963, whole-body measurements were initiated at Risø in the low-level counting room in the Health Physics Department (cf. 2.3 in Risø Report No. 85[1]). A control group from the Health Physics Department was selected and has since then been measured three times a year. Table 6.2 shows the results.

The annual mean value of the control group was 16 pCi ^{137}Cs/g K. As earlier, we shall consider this figure representative of the mean of the Danish population in 1972. The total-body content of ^{137}Cs in 1972 for a standard man containing 140 g of potassium equals $140 \cdot 16 \cdot 10^{-3}$ nCi = 2.2 nCi ^{137}Cs, i.e. a little higher than the 1971 level.

Fig. 6.2 shows the mean M.U. values (with one S.D.) for men and women measured in 1963-1971.

The maximum was reached in August 1964. The figure also shows that the mean level in the male group was approx. 1.3 - 1.5 times as high as that in the female group.

Table 6.2

Whole-body measurements of caesium-137 and potassium in 1972

No.	Sex	Counting date	Age	Height in cm	Weight in kg	pCi Cs-137/g K	pCi Cs-137/kg	g K/kg body weight
2	F	April	24	170	61	14.8	26.1	1.8
5	F	-	28	171	99	6.3	7.5	1.2
6	F	-	35	164	59	14.9	21.2	1.4
7	F	-	44	171	64	17.9	29.6	1.7
8	M	-	40	193	80	18.9	34.3	1.8
9	M	-	44	170	66	16.5	32.4	2.0
10	F	-	25	164	46	19.6	36.7	1.9
11	F	-	33	180	71	11.9	20.3	1.7
12	M	-	34	174	72	10.4	21.9	2.1
13	F	-	40	161	56	16.1	31.7	2.0
15	F	-	36	165	53	16.2	28.0	1.7
18	M	-	33	178	76	7.4	14.6	2.0
19	M	-	29	174	73	18.8	37.3	2.0
20	M	-	40	172	66	21.6	46.2	2.1
21	F	-	51	176	65	13.2	21.5	1.6
22	M	-	49	183	76	25.3	61.7	2.4
23	M	-	42	192	89	32.1	59.1	1.8
24	M	-	41	170	71	15.8	34.9	2.2
25	F	-	30	167	57	14.8	21.7	1.5
26	F	-	33	160	56	19.7	34.8	1.8
30	M	-	26	168	58	14.3	30.2	2.1
31	M	-	30	182	78	21.6	45.5	2.1
32	F	-	43	157	64	11.7	17.5	1.5
33	M	-	41	184	63	24.4	58.0	2.4
36	F	-	26	158	45	13.8	26.5	1.9
37	M	-	35	175	68	22.9	49.1	2.1
91	M	-	47	174	86	13.9	23.8	1.7
5	F	Sept.	28	171	99	11.1	14.8	1.3
7	F	-	44	171	64	11.9	15.0	1.3
8	M	-	40	193	80	31.1	53.1	1.7
9	M	-	44	170	66	11.3	27.7	2.5
12	M	-	34	174	74	25.6	32.3	1.3
19	M	-	29	174	72	10.2	10.9	1.1
20	M	-	40	172	62	9.5	15.5	1.6
21	F	-	51	176	65	8.5	9.5	1.1
24	M	-	41	170	71	14.6	24.8	1.7
30	M	-	26	168	58	15.2	46.5	3.0
33	M	-	41	184	63	20.1	46.1	2.3
34	M	-	30	177	72	5.5	12.5	2.3
35	M	-	31	181	74	17.9	20.1	1.1
37	M	-	35	175	63	22.3	28.1	1.3
39	F	-	23	172	62	7.7	11.7	1.5

(6.2. continued)

No.	Sex	Counting date	Age	Height in cm	Weight in kg	pCi Cs-137/g K	pCi Cs-137/kg	g K/kg body weight
40	M	-	25	187	73	8.6	13.0	1.5
42	M	-	44	172	58	16.2	22.0	1.4
43	M	-	55	167	68	12.9	15.6	1.2
91	M	-	47	174	91	8.3	14.3	1.7
2	F	Dec.	24	170	54	14.6	26.1	1.8
4	F	-	48	161	60	9.2	14.9	1.6
5	F	-	28	171	88	15.2	20.7	1.4
7	F	-	44	171	64	15.4	26.2	1.7
8	M	-	40	193	79	28.1	51.8	1.8
9	M	-	44	170	65	7.3	10.9	1.5
12	M	-	34	174	76	20.9	42.8	2.0
13	F	-	40	161	56	12.9	24.0	1.9
15	F	-	36	165	53	12.9	20.4	1.6
17	F	-	32	159	57	12.0	18.6	1.5
18	M	-	33	178	73	13.0	24.1	1.9
19	M	-	30	174	72	23.1	40.2	1.7
20	M	-	40	172	65	21.0	38.3	1.8
21	F	-	51	176	65	13.8	24.2	1.8
23	M	-	42	192	87	17.9	31.7	1.8
24	M	-	41	170	75	27.9	58.1	2.1
25	F	-	30	167	57	13.9	20.0	1.4
26	F	-	33	160	56	14.6	24.7	1.7
30	M	-	26	168	58	18.6	39.6	2.1
31	M	-	30	182	78	19.2	35.1	1.8
32	F	-	43	157	64	14.1	21.5	1.5
33	M	-	41	184	63	15.7	34.1	2.2
34	M	-	30	177	69	8.2	17.0	2.1
35	M	-	31	181	74	51.5	97.8	1.9
37	M	-	35	175	65	18.6	38.0	2.0
39	F	-	23	172	62	9.8	13.9	1.4
40	M	-	25	187	73	11.2	26.4	2.4
42	M	-	44	172	59	32.1	66.2	2.1
43	M	-	55	167	68	13.6	25.8	1.9
44	F	-	22	170	58	4.0	6.6	1.6
45	F	-	25	167	59	13.4	30.2	2.2
46	M	-	44	176	76	19.1	36.9	1.9
48	F	-	33	162	50	17.1	30.8	1.8

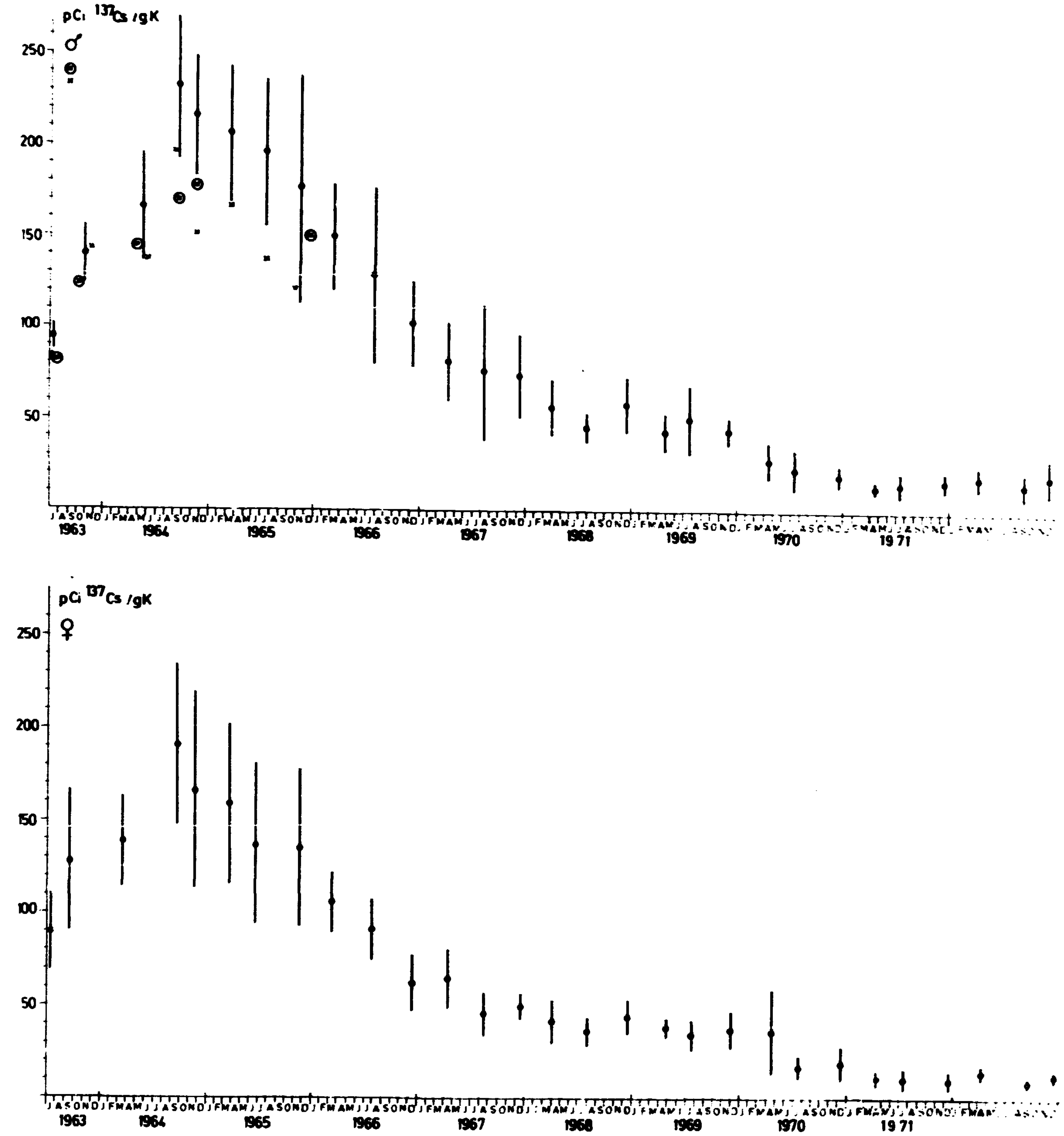

Fig. 6.2. Caesium-137 mean levels in humans, 1963-72 (1 S.D. indicated).

7. STRONTIUM-90 AND CAESIUM-137 IN SEA WATER IN 1972

The collection of sea-water samples initiated in 1961-62 was continued in 1972. The samples were collected by the M/S Fyrholm in June and December around Zealand at the same locations as in 1970 and 1971 (cf. tables 7.1 and 7.2) and by the DANA in February and September (cf. tables 7.3 and 7.4).

Brogmus[18] has proposed an equation for the water balance of the Baltic Sea:

$$\underset{500\ km^3}{\text{Run off}} + \underset{200\ km^3}{\text{precipitation}} + \underset{500\ km^3}{\text{inflow}} = \underset{1000\ km^3}{\text{outflow}} + \underset{200\ km^3}{\text{evaporation}} \qquad (1)$$

Let us consider the period 1967-71 when the "^{90}Sr-fall-out situation" has been stabilized, i.e. the variations in annual ^{90}Sr fall-out rate and in accumulated ^{90}Sr fall-out have been relatively small[1] and annual mean levels in sea water from the inner Danish waters (cf. fig. 7.2) have been rather constant (cf. fig. 7.1). Let us assume that the mean level in "run off" (river and stream water) for the period was equal to the measured mean level for Danish streams determined in 1970-71, i.e. 0.40 ± 0.03 pCi ^{90}Sr/l (cf. table 4.4)[1] and that the mean level in "precipitation" equals the Danish mean level for 1967-71, i.e.: 1.96 ± 0.19 pCi ^{90}Sr/l (cf. table 4.4.1)[1]. The ^{90}Sr activity in "inflow" was considered equal to the mean ^{90}Sr level in bottom water with a salinity greater than 30 o/oo collected during the period in inner Danish waters, i.e. 0.31 ± 0.04 pCi ^{90}Sr/l (11 samples, mean, salinity: 33.1 ± 0.5 o/oo). The ^{90}Sr mean level in "outflow" was calculated as the mean ^{90}Sr activity in surface water from the south-eastern stations in fig. 7.2, (i.e. the stations south of 55°20' N and east of 12°00' E), the mean level for the period became 0.76 ± 0.03 pCi ^{90}Sr/l (17 samples, mean salinity: 10.4 ± 0.5 o/oo). Let us now calculate the left side in the Brogmus equation (1): $(500 \cdot 0.40 + 200 \cdot 1.96 + 500 \cdot 0.31)$Ci = 747 Ci ^{90}Sr and compare it with the right side: $(1000 \cdot 0.76)$ Ci = 760 Ci ^{90}Sr. Hence we may conclude that the annual mean outflow from the Baltic through the Danish waters during the period 1967-71 was approx. 750 Ci ^{90}Sr and the inflow from the North Sea approx. 150 Ci ^{90}Sr.

Table 7.1

Sr-90 and Cs-137 in sea water collected around Zealand in June and December 1972

	Position		June			December			
	N	E	depth in m	Sr-90 pCi/l	Salinity o/oo	depth in m	Sr-90 pCi/l	Salinity o/oo	Cs-137 pCi/l
Kullen	56°15'	12°25'	0	0.62	17.9	0	0.86	13.6	1.03
"			22	0.45	27.2	21	0.53	27.4	0.78
Hesselø	56°10'	11°47'	0	0.25	18.4	0	0.55	26.9	0.71
"			28	0.43	27.2	26	0.44	27.7	0.62 A
Kattegat SW	56°07'	11°10'	0	0.51	17.1	0	0.53	10.6	0.77
"			30	0.22	34.0	35	0.34	30.6	0.77
Asnæs rev	55°33'	10°47'	0	0.72	13.6	0	0.51	23.9	0.75
" "			45	0.26	26.5	50	0.44	28.8	0.81
Halskov rev	55°20'	11°02'	0	0.68	16.7	0	0.27	19.7	0.39 B
" "			48	0.20	32.8	41	0.53	25.2	0.68
Langeland bælt	54°52'	10°50'	0	0.56	18.1	0	0.61	20.2	0.51
" "			50	0.34	24.4	46	0.61	21.0	0.67
Femern bælt	54°36'	11°05'	0	0.84	11.5	0	0.61	18.4	0.88
" "			27	0.38	22.5	26	0.65	19.4	0.74
Gedser rev	54°28'	12°13'	0	0.70	14.5	0	0.73	12.5	0.92
" "			27	0.52	20.8	26	0.63	15.6	0.57
Stevns	55°16'	12°34'	-	-	-	-	-	-	-
"			-	-	-	-	-	-	-
The Sound - south	55°25'	12°39'	0	0.91	8.2	0	0.82	12.1	0.59
" " "			12	0.92	6.5	12	0.74	12.6	1.03
The Sound - north A	55°48'	12°44'	0	0.75	8.6	-	-	-	-
" " "			-	-	-	19	0.48	27.4	0.61 A
The Sound - north B	55°59'	12°42'	-	-	-	0	0.58	12.6	0.74
" " "			-	-	-	27	0.46	28.8	0.71
Mean			surface	0.65	14.5	surface	0.61	16.2	0.73
SD				0.19	3.9		0.17	4.5	0.19
SE				0.06	1.2		0.05	1.4	0.06
Mean			bottom	0.41	24.7	bottom	0.53	24.0	0.73
SD				0.22	8.1		0.12	6.0	0.13
SE				0.07	2.7		0.03	1.8	0.04

Table 7.2

Sr-90 and Cs-137 in sea water collected in the Sound (Barsebäck) in 1972

Position		March				June				October				December			
N	E	depth in m	Sr-90 pCi/l	Cs-137 pCi/l	Salinity o/oo	depth in m	Sr-90 pCi/l	Cs-137 pCi/l	Salinity o/oo	depth in m	Sr-90 pCi/l	Cs-137 pCi/l	Salinity o/oo	depth in m	Sr-90 pCi/l	Cs-137 pCi/l	Salinity o/oo
55°42'08"N	12°54'E	0	0.63	0.43		0	0.78		8.3	0	0.86±0.07	0.78±0.01	10.8±2.4				
- " -	- " -	bottom	0.41	0.50		13	0.27		32.4	10	1.27	0.81	22.0	14	0.44	0.65	29.6
55°47'05"N	12°51'07"E	0	0.38	-		0	0.99		6.7					0	0.41	0.83	14.5
- " -	- " -	bottom	0.33	-		17	0.25		26.7					16	0.36	0.61	29.6
55°44'N	12°51'E									0	0.77	0.65	8.8				
- " -	- " -									17	0.33	0.68	31.4				
55°48'N	12°44'E					0	0.75		8.6	0	0.54	0.81	18.0				
- " -	- " -																
54°57'N	12°41'E					0	0.84		6.4					0	0.82	0.73	9.2
- " -	- " -					20	0.69		11.6					21	0.91	0.51	25.2
Mean		surface	0.51	0.43		surface	0.87		7.1	surface	0.72	0.75		surface	0.62	0.78	
SD			0.18				0.11		1.0		0.17	0.09			0.29	0.07	
SE			0.12				0.06		0.6		0.10	0.05			0.21	0.05	
Mean		bottom	0.37	0.50		bottom	0.40		23.6	bottom	0.80	0.75		bottom	0.57	0.59	
SD			0.06				0.25		10.8		0.66	0.09			0.30	0.07	
SE			0.04				0.14		6.2		0.47	0.07			0.17	0.04	

In fig. 7.3 is shown a regression line calculated from all data (129 samples) from inner Danish waters obtained during 1967-71. We found a significant linear regression of the form

$$\text{pCi } {}^{90}\text{Sr/l} = 0.94 - 0.018 \text{ salinity in o/oo} \qquad (2)$$

In the figure we have further more plotted the 1972 data (table 7.1 and 7.2) and shown their regression line (3):

$$\text{pCi } {}^{90}\text{Sr/l} = 0.97 - 0.020 \text{ salinity in o/oo} \qquad (3)$$

We conclude from the figure that the 1972 data as a whole did not deviate significantly from the 1967-71 regression line (2). A few samples, e.g. a sample from October 1972 (salinity 22 o/oo) (cf. table 7.2), did not belong to the same population as the bulk of the data.

The ^{90}Sr levels from the northern and western part of the Danish waters collected in February 1972 (table 7.3) also fit (2). However, if we look at the North Sea data in table 7.4 it is evident that five of the eight samples deviate significantly from the regression line (2). In fig. 7.4 the locations are shown and it appears that the levels increase as one approaches the northern part of Scotland. The surplus ^{90}Sr probably arise from a British nuclear facility in northern Scotland.

Table 7.3

Sr-90 and Cs-137 in sea water collected in the North Sea, Skagerak and Kattegat in February 1972

Position	Sr-90 pCi/l	Cs-137 pCi/l	Salinity o/oo
54°39'N 07°50'E	0.36±0.01		32.1
52°39'N 02°14'E	0.49		33.8
54°26'N 0°32'E	0.50±0.02		34.6
57°21'N 05°24'E	0.31		34.4
57°21'N 03°24'E	*0.31±0.02		34.9±0.1
57°38'N 09°51'E	0.25	0.55 A	34.2
57°27'N 10°40'E	0.66	0.79 A	20.5
Mean	0.41	0.67	
SD	0.14	0.17	
SE	0.05	0.12	

The error term is the SE of the mean of double determinations except * which were quadruple determinations.

A: relative S.D.: 20-33%

Table 7.4

Sr-90 and Cs-137 in sea water collected by the DANA in the North Sea in September 1972

Position	Sr-90 pCi/l	Cs-137 pCi/l	Salinity o/oo
57°46'N 10°00'E	0.36	0.79	31.2
58°15'N 3°20'W	1.37	3.99	34.6
60°55'N 0°10'E	0.19	0.31 B	35.0
58°35'N 02°50'W	1.72	3.72	34.2
57°24'N 05°00'E	0.36	0.27 B	35.0
57°15'N 01°00'E	0.72	1.29	34.9
59°25'N 02°10'W	1.51	2.80	34.6
58°45'N 03°50'W	2.68	5.42	34.2

B: relative S.D.: >33%

Caesium-137 was determined in the samples from the autumn and the winter in 1972. The results appear in the tables along with the ^{90}Sr determinations. Salo and Voipo[19] and the German Hydrografic Institute in Hamburg[20] have shown that the $^{137}Cs/^{90}Sr$ ratios in the Baltic Sea water are approx. one or a little less. In "normal" sea water (35 o/oo salinity) the ratio is approx. 1.6 ± 0.1[16].

If we relate the $^{137}Cs/^{90}Sr$ ratios in sea water from 1972 to the salinity we get the regression:

$$^{137}Cs/^{90}Sr = 0.77 + 0.026 \text{ salinity in o/oo} \qquad (4)$$

From (4) we can calculate the $^{137}Cs/^{90}Sr$ ratio in 35 o/oo sea water to 1.7 and in 10 o/oo sea water to 1.0. These levels are in reasonable agreement with the above mentioned figures. The mean $^{137}Cs/^{90}Sr$ ratio in the North Sea samples with surplus ^{90}Sr in table 7.4 is 2.2 ± 0.2, the $^{137}Cs/^{90}Sr$ ratio in these samples is thus perhaps a little higher than the expected ratio.

8.4.3. A Location in Zealand

As it is important to have knowledge of the preoperational radiation levels before a nuclear power plant goes critical, it was in 1967 decided to initiate such measurements at a location in Zealand (and one in Jutlant) which might be used for nuclear power plants in the future.

The area around the location was divided into four zones: A, B, C, and D, with radii of 5, 10, 15, and 20 km respectively. The zones were each

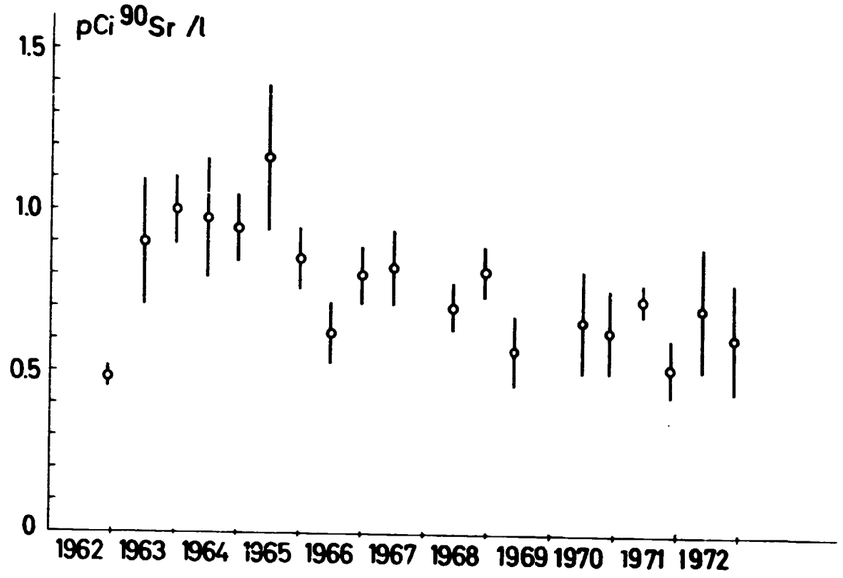

Fig. 7.1. Strontium-90 in surface sea water from inner Danish waters, 1962-72 (1 S.D. indicated). (From table 7.1).

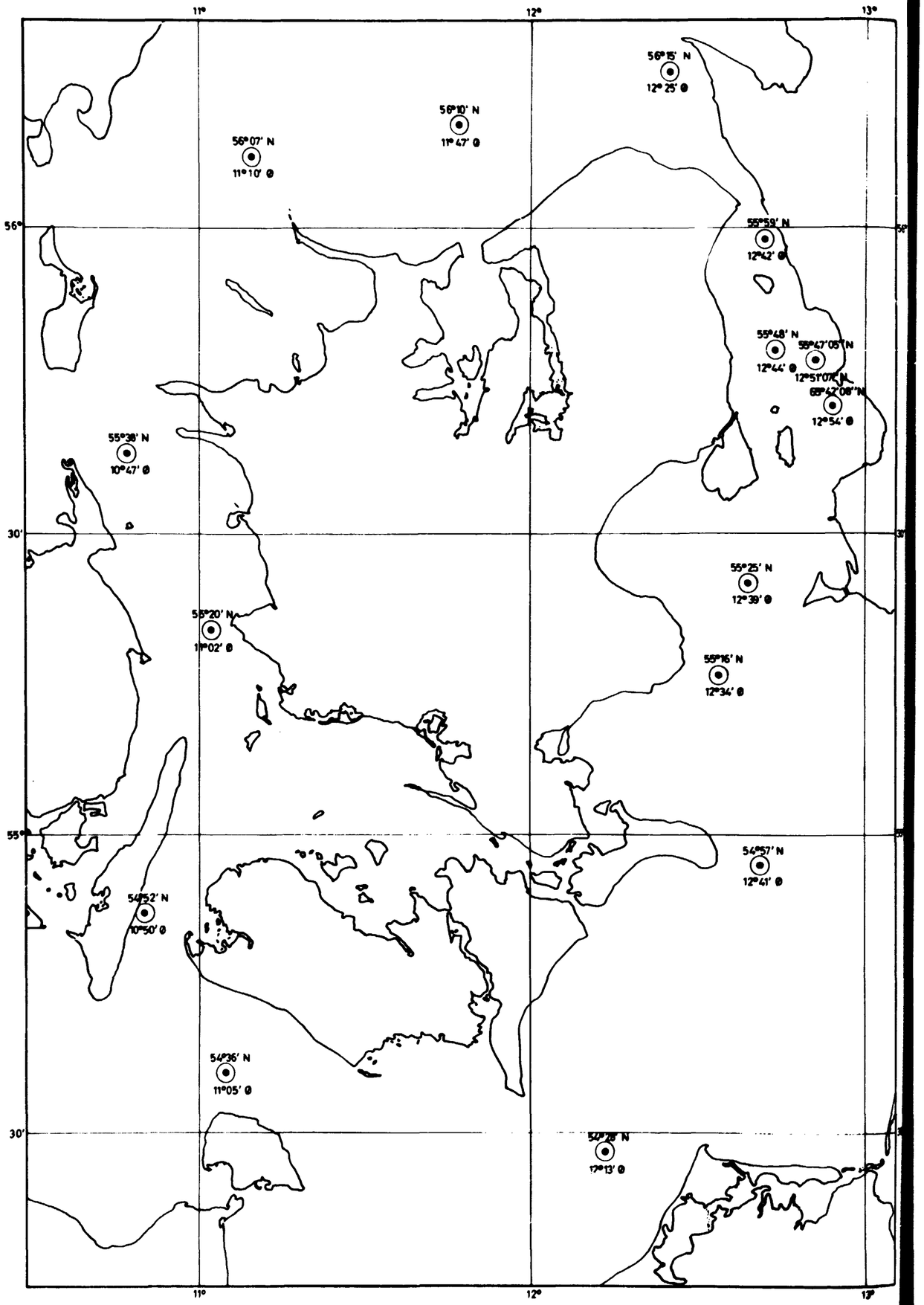

Fig. 7.2. Sea-water locations around Zealand.

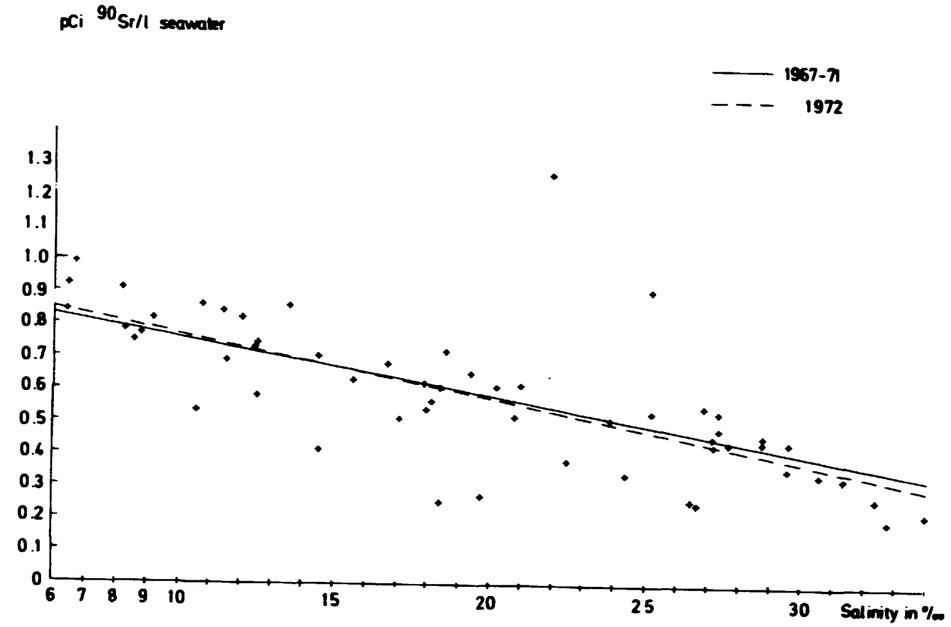

Fig. 7.3. Strontium-90 in Danish sea water as a function of salinity.
(+ observed values in 1972).

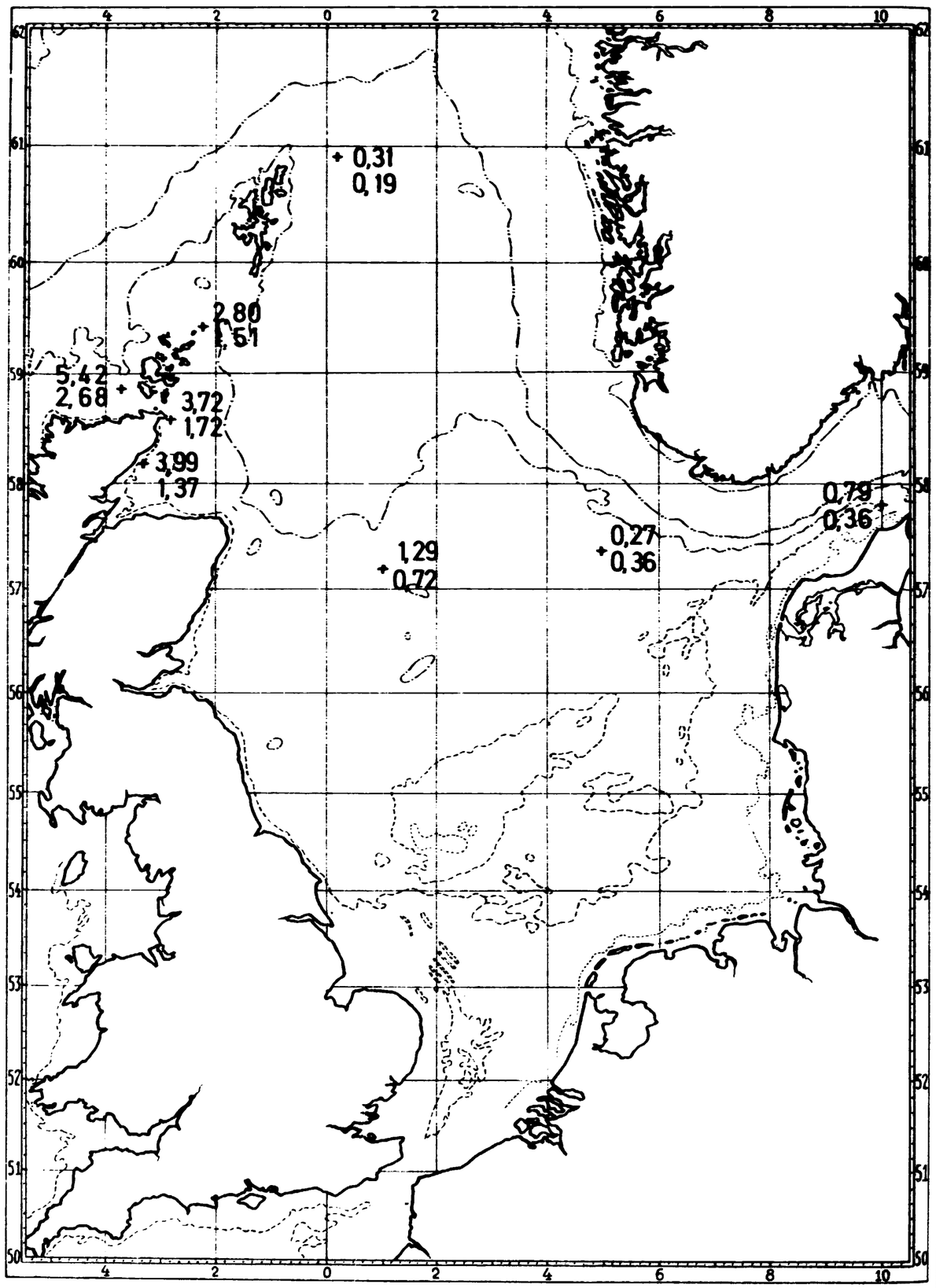

Fig. 7.4. Caesium-137 (upper figure) and Strontium-90 (lower figure) in surface sea water collected in the North Sea in september 1972.

8. SPECIAL SURVEYS

8.1. Meteorological Mast Experiment

As in previous years, samples of precipitation were collected from the meteorological mast at Risø at eight different heights. The ^{90}Sr analyses were, as in 1971, carried out on quarterly samples.

Table 8.1.1 shows the ^{90}Sr levels in the eight bottles throughout the year. An analysis of variance of the natural logarithm of the pCi $^{90}Sr/l$ and the mCi $^{90}Sr/km^2$ figures showed as previously that the variations between months were highly significant ($P > 99.95\%$). The variations between the different locations were significant ($P > 99.5\%$) in the case of pCi/l, but not for mCi/km^2.

The mean amount of precipitation in the eight bottles on the mast was 450 mm in 1972, i. e. 96% of the level measured in rain bottles at ground level at Risø (cf. table 3.2.4.1). The total deposition was 0.47 mCi $^{90}Sr/km^2$, i. e. 40% higher than the level measured at the ground stations at Risø (cf. 3.2.4).

Table 8.1.1

Sr-90 in the meteorological mast 1972

	0 m		7 m		23 m		39 m	
	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
Jan. Feb. Mar.	0.854	0.0633	1.33	0.105	1.47	0.134	1.42	0.159
Apr. May June	1.01	0.159	1.30	0.199	1.21	0.184	1.19	0.180
July Aug. Sep.	0.643	0.0797	0.868	0.109	0.946	0.112	0.954	0.119
Oct. Nov. Dec.	0.441	0.0468	0.600	0.0542	0.425	0.0411	0.458	0.0494
1972	$\bar{x}$ 0.757	Σ 0.349	$\bar{x}$ 1.04	Σ 0.467	$\bar{x}$ 1.03	Σ 0.471	$\bar{x}$ 1.02	Σ 0.507
	461 mm		448 mm		459 mm		496 mm	

56 m		72 m		96 m		123 m		Mean	
pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
1.56	0.150	1.77	0.219	1.78	0.163	2.07	0.0958	1.53	0.136
1.38	0.202	1.23	0.194	1.28	0.180	1.27	0.165	1.23	0.183
1.03	0.120	0.930	0.111	0.918	0.100	0.798	0.0825	0.886	0.104
0.483	0.0450	0.523	0.0512	0.529	0.0453	0.658	0.0526	0.515	0.0482
$\bar{x}$ 1.14	Σ 0.517	$\bar{x}$ 1.16	Σ 0.575	$\bar{x}$ 1.14	Σ 0.488	$\bar{x}$ 1.10	Σ 0.396	$\bar{x}$ 1.05	Σ 0.471
453 mm		498 mm		427 mm		359 mm		450 mm	

8.2. Fission Product Ratios in Air Samples Collected in the Meteorological Mast in 1972

Air samplers of the injector type have been installed in the meteorological mast at the same altitudes as the rain bottles. Each sampler was equipped with an 8-cm glass-fibre filter which was changed every Monday. The thirteen filters from three months were combined to a quarterly sample from each height. The total amount of air in a sample was approx. 7500 m^3. The samples were counted on a Ge(Li) detector for 24 hours. Strontium-90 was also determined. The levels in October-December were too low for a reliable determination.

Table 8.2.1

Ce-141/Ce-144 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1972

	Jan.-Mar.	Apr.-June	July-Sep.
0 m	-	0.80	0.51
7 m	0.60	0.54	0.50
23 m	-	1.12	0.57
39 m	0.47	1.03	0.44
56 m	0.29	1.47	0.43
72 m	0.23	1.88	0.34
96 m	-	1.06	0.33
123 m	0.18	1.02	0.44
$\bar{x}$	0.35	1.12	0.44
η	0.50	0.37	0.18

Table 8.2.2

Zr-95/Ce-144 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1972

	Jan.-Mar.	Apr.-June	July-Sep.
0 m	0.52	1.11	0.77
7 m	0.28	0.89	0.86
23 m	0.40	0.83	0.83
39 m	0.42	0.84	0.85
56 m	0.46	0.99	0.72
72 m	0.31	1.44	0.76
96 m	0.82	1.76	0.86
123 m	0.82	1.35	0.78
$\bar{x}$	0.50	1.15	0.80
η	0.42	0.29	0.07

Tables 8.2.1-8.2.6 show isotope ratios determined at the different heights. Analyses of variance were carried out on the ratios. We found that $^{95}Zr/^{137}Cs$ ratio differed probably significantly with altitude (the ratio was higher at 96 m than at 7 m). A similar observation was made in 1965 (cf. Risø Report No. 130, p. 86)[1].

Table 8.2.3

Zr-95/Cs-137 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1972

	Jan.-Mar.	Apr.-June	July-Sep.
0 m	3.22	10.94	4.65
7 m	1.25	8.03	3.74
23 m	1.79	7.60	3.98
39 m	2.29	8.54	3.93
56 m	1.87	7.85	4.29
72 m	1.55	8.46	4.31
96 m	2.89	13.23	5.83
123 m	3.74	6.48	3.56
$\bar{x}$	2.32	8.89	4.29
n	0.38	0.24	0.17

Table 8.2.4

Ru-106/Zr-95 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1972

	Jan.-Mar.	Apr.-June	July-Sep.
0 m	1.05	0.29	0.98
7 m	3.22	0.61	0.88
23 m	1.20	0.47	1.15
39 m	2.12	0.41	0.46
56 m	1.27	0.46	0.94
72 m	1.80	0.42	0.54
96 m	0.54	0.21	0.79
123 m	1.00	0.39	0.76
$\bar{x}$	1.53	0.41	0.81
n	0.55	0.29	0.28

Table 8.2.5

Ru-103/Ru-106 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1972

	Jan.-Mar.	Apr.-June	July-Sep.
0 m	0.56	2.53	0.87
7 m	-	1.21	0.93
23 m	0.74	1.80	1.14
39 m	0.86	1.64	1.90
56 m	0.62	1.51	0.99
72 m	-	1.38	0.97
96 m	1.15	2.00	1.24
123 m	0.55	2.22	0.84
$\bar{x}$	0.75	1.79	1.11
n	0.31	0.25	0.31

Table 8.2.6

Cs-137/Sr-90 in air filters collected quarterly at 8 different heights in the meteorological mast at Risø in 1972

	Jan.-Mar.	Apr.-June	July-Sep.
0 m	1.45	1.35	1.49
7 m	1.81	1.66	1.91
23 m	1.86	1.49	1.40
39 m	1.40	1.61	2.07
56 m	1.84	1.30	1.44
72 m	1.59	1.61	1.55
96 m	1.74	1.56	1.20
123 m	1.53	1.89	1.42
$\bar{x}$	1.65	1.56	1.56
n	0.11	0.12	0.18

8.3. Human Milk

No human milk samples were collected in 1972.

8.4. Country-wide Measurement of the Y-Background in 1972

8.4.1. State Experimental Farms

As in previous years[1], the Y-background was measured in March, June, September, and December at ten State experimental farms. Table 8.4.1.1 shows the results, and table 8.4.1.2 gives the analysis of variance. The variations between locations were highly significant (P〉 99.95%). As in previous years, it was evidently not the fall-out that determined the variation between locations.

In the last part of 1972 the Y-measurements were performed with a new NaJ-crystal, because the efficiency of the old one had been decreasing for the last years (cf. Risø Report No. 265[1]).

Fig. 8.4 shows the Y-background in four groups of sampling stations since 1962. The fact that stations with a low fall-out rate and a high clay content in the soil (Abed, Blangstedgård, and Tystofte) show higher Y-levels than stations with a high fall-out rate and a low clay content (but a high sand content) (Studsgård, St. Jyndevad, and Askov) was discussed in Risø Report No. 154[1].

Table 8.4.1.1

Y-background at the state experimental farms in 1972 (μR/h)
(Correction factor 1.40 has been applied to March and June)

	Mar.	June	Sep.	Dec.	Mean
Tylstrup	4.8±0.1	4.8±0.1	4.9±0	5.6±0	5.0
Studsgård	4.6±0	4.6±0	4.0±0	4.2±0.1	4.4
Ødum	5.7±0.1	6.4±0	6.2±0.1	5.7±0.1	5.8
Askov	5.7±0.1	5.0±0.2	5.5±0.1	5.3±0	5.4
St. Jvndevad	4.6±0	4.1±0	3.9±0.1	4.8±0.1	4.4
Blangstedgård	6.2±0.3	5.9±0.2	6.3±0.2	6.2±0.1	6.2
Tystofte	7.1±0.1	7.3±0.2	6.6±0.1	6.9±0.1	7.0
Virumgård	7.3±0.2	7.3±0.2	6.5±0.1	5.6±0	6.7
Abed	7.0±0.2	7.1±0.1	4.2±0.2	6.4±0	6.2
Åkirkeby	(8.6)	9.2±0.1	(7.9)	7.4±0	(8.3)
Mean	(6.2)	6.2	(5.6)	5.8	

The error term is the S.E. of the mean of 6 determinations.

Table 8.4.1.2

Analysis of variance of the Y-background
at the state experimental farms in 1972
(from table 8.4.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	250.9010	9	27.8779	12.61	>99.95%
Between months	14.4789	3	4.8263	2.18	>70%
Loc. x months	55.2780	25	2.2112	27.68	>99.95%
Remainder	14.9404	187	0.0799		

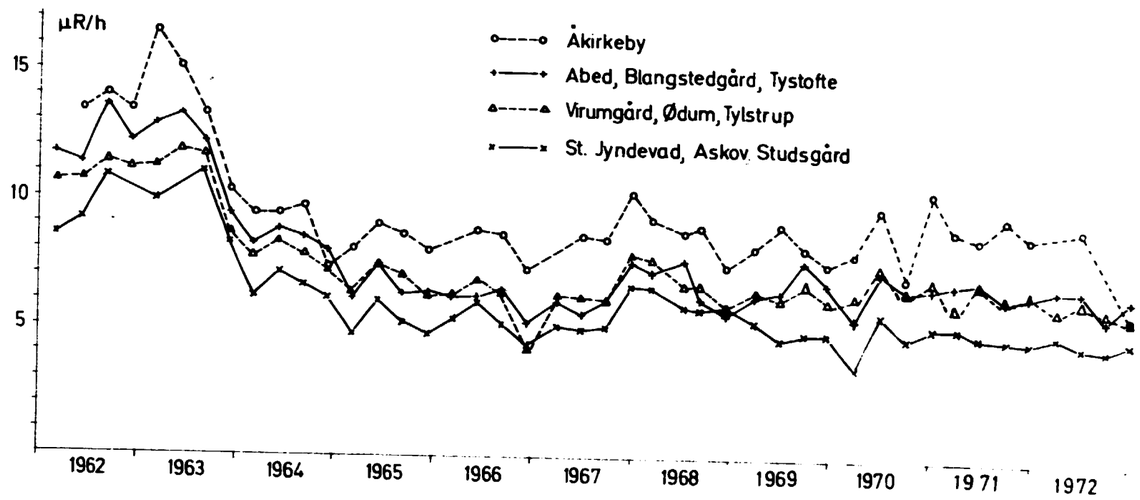

Fig. 8.4. The Y-background in the State experimental farms, 1962-72.

8.4.2. The Risø Environment

Y-background measurements were performed in the five zones round Risø in July. The measurements were carried out at the locations where grass and soil are collected (cf. figs. 3.1.2.1 and 3.1.2.2 (the coloured map)).

Table 8.4.2 shows the results.

At all locations in zone I and at location 2 in zone II the Y-background had increased because of the various radiation sources at the research establishment. The weighted annual mean for zones III-V was 6.2 μR/h. In zone I the surplus activity from the research establishment was 11.2 - 6.2 = 5.0 μR/h (in 1967: 4.0, in 1968: 3.9, in 1969: 3.3, in 1970: 4.7, and in 1971: 1.6). A man working in the open in the Risø area 40 hours a week for 45 weeks a year would thus get a surplus dose of 9 mR/year.

Table 8.4.2

γ-background (μR/h) in the five zones around Risø in 1972
(Correction factor 1.40 has been applied to all data)

Risø zone (cf. coloured map)	Location	July
I	1	5.9
-	2	8.2
-	3	21.4
-	4	10.5
-	5	10.0
Mean		11.2
II	1	5.9
-	2	9.1
-	3	6.8
-	4	6.4
Mean		7.0
III	1	7.3
-	2	6.4
-	3	6.4
-	4	5.9
Mean		6.5
IV	1	6.4
-	2	7.3
-	3	6.4
-	4	5.9
-	5	5.9
-	6	5.9
-	7	6.4
-	8	7.3
Mean		6.4
V	1	5.5
-	2	6.4
-	3	5.9
-	4	5.5
-	5	5.9
-	6	5.9
-	7	5.0
-	8	6.8
-	9	5.5
-	10	5.5
-	11	6.4
-	12	6.4
Mean		5.9

Table 8.4.3

γ-background (μR/h) around a location in Zealand in 1972
(Correction factor 1.40 has been applied to all data)

Zone and sector	July
A 2	5.5
A 3	5.0
A 4	6.4
A 5	5.9
A 6	5.9
A 7	5.9
A 8	5.9
A 9	6.4
Mean	5.9
B 1	5.0
B 2	6.4
B 3	6.4
B 4	5.5
B 5	7.3
B 6	5.9
B 7	5.5
B 8	6.8
B 9	6.4
B 10	5.5
Mean	6.1
C 1	5.0
C 2	5.0
C 3	5.5
C 4	5.5
C 5	7.3
C 6	6.4
C 7	6.8
C 8	7.3
C 9	5.9
C 10	6.4
C 11	5.0
C 12	5.0
Mean	5.9
D 1	5.5
D 2	5.5
D 3	5.5
D 4	6.4
D 5	6.4
D 6	5.5
D 7	5.9
D 8	8.2
D 9	5.0
D 10	6.4
D 11	5.9
D 12	5.0
Mean	5.9

Table 8.4.4

γ-background (μR/h) around a location in Jutland in 1972
(Correction factor 1.40 has been applied to all data)

Zone and sector	July
A 1	6.8
A 2	7.3
A 3	6.4
A 4	5.5
A 5	7.3
A 6	5.5
A 7	5.5
A 8	4.6
A 9	4.6
A 10	5.5
A 11	5.9
A 12	5.9
Mean	5.9
B 1	5.9
B 2	6.8
B 4	5.5
B 5	6.4
B 6	5.5
B 7	6.8
B 8	5.5
B 9	5.5
B 10	5.5
B 11	5.9
B 12	5.9
Mean	5.9
C 1	6.4
C 2	7.7
C 3	4.6
C 4	6.8
C 5	6.8
C 6	5.5
C 7	6.4
C 8	5.5
C 9	5.5
C 10	4.6
C 11	5.5
C 12	6.4
Mean	6.0
D 1	5.5
D 2	5.9
D 3	6.4
D 4	7.3
D 5	4.6
D 6	5.9
D 7	6.4
D 8	5.0
D 9	4.6
D 10	5.5
D 11	5.0
D 12	5.5
Mean	5.6

divided into 12 30° sectors, sector 1 being from due north and 30° clockwise, sector 2 from 30 to 60°, and so on. A measuring location was thus determined by a zone letter and a sector number. Locations in the sea were omitted.

Table 8.4.3 shows the results. The annual mean for all locations was 6.0 μR/h, i.e. nearly equal to the level found in zones III-V around Risø.

8.4.4. A Location in Jutland

Table 8.4.4 shows a similar investigation as in 8.4.3 for a location in Jutland. The annual mean for all locations was 5.9 μR/h, i.e. equal to the levels of Zealand (cf. 8.4.2 and 8.4.3).

8.4.5. The Coasts of the Great Belt

The Great Belt is a main shipping route for international traffic through inner Danish waters. Occasionally this waterway will be passed by nuclear ships. An environmental γ-survey of the coastline along the Great Belt has therefore been initiated. Table 8.4.5 shows the results. The levels were a little lower than those found in most of the other parts of the country. The annual mean was 6.1 μR/h.

Table 8.4.5

The γ-background (μR/h) along the coasts of the Great Belt in 1972
(Correction factor 1.40 has been applied to all data)

Location	July
Agersø	4.6
Omø	4.6
Røsnæs	4.1
Reersø	6.4
Halskov	8.7
Sprogø	5.9
Knudshoved	5.9
Risinge	5.5
Fyns Hoved	6.8
Tårup Strand	5.9
Hov, Langeland	5.9
Tranekær	5.9
Vindeby Strand	6.4
Kelds Nor	9.1
Mean	6.1

9. CONCLUSION

9.1. Risø Environmental Monitoring

No radioactive contamination of the environment originating from the operation of the research establishment was ascertained outside Risø in 1972. As in previous years, the variations in contamination level were independent of the distance of the sampling locations from Risø.

9.2. Nuclear-Weapon Debris in Air, Precipitation, Soil, Ground Water, and Surface Water

The mean content of ^{90}Sr in air collected in 1972 was 0.0008 pCi $^{90}Sr/m^3$, i.e. approx. 40% of the 1971 level. The average fall-out at the State experimental farms in 1972 was 0.44 mCi $^{90}Sr/km^2$ or approx. 30% of the 1971 figure, and the mean concentration of ^{90}Sr in rain water was 0.73 pCi $^{90}Sr/l$.

By the end of 1972 the accumulated fall-out down to a depth of 30 cm was approx. 52 mCi $^{90}Sr/km^2$. From 0-20 cm the level was 46 mCi $^{90}Sr/km^2$.

In agreement with the greater amounts of precipitation in that part of the country the fall-out levels in Jutland were 15-25% higher than the levels found in eastern Denmark.

The median level of ^{90}Sr in Danish ground water was 0.1 pCi $^{90}Sr/l$.

9.3. Strontium-90 and Caesium 137 in the Human Diet

The mean level of ^{90}Sr in Danish milk was 6.6 S.U., and the mean content of ^{137}Cs was approx. 11 pCi $^{137}Cs/l$.

The 1972 ^{90}Sr and ^{137}Cs levels were 10-20% lower than the levels found in milk produced in 1969-71.

The ^{90}Sr mean content in grain from the 1972 harvest was 38 pCi $^{90}Sr/kg$. The ^{137}Cs mean content in grain was 25 pCi $^{137}Cs/kg$. The ^{90}Sr level in grain from the 1972 harvest was 2/3 of the level found in the 1971 harvest, and ^{137}Cs was approx. 1/3 of the 1971 level.

The mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1972 were 12 pCi $^{90}Sr/kg$ (30 S.U.) and 2.4 pCi $^{137}Cs/kg$ respectively, and in fruits 2.7 pCi $^{90}Sr/kg$ and 5 pCi $^{137}Cs/kg$; potatoes contained 2.9 pCi $^{90}Sr/kg$ and 5 pCi $^{137}Cs/kg$.

The mean levels of ^{90}Sr and ^{137}Cs in total-diet samples collected in 1972 were 7.8 S.U. or 13.7 pCi ^{90}Sr/day and 30 pCi ^{137}Cs/day respectively. From analyses of the individual diet components the ^{90}Sr level in the Danish average diet was estimated to be 8.2 S.U. and the ^{137}Cs intake to be 30 pCi ^{137}Cs/day. The ^{90}Sr levels in the Danish total diet consumed in 1972 were nearly equal to the 1971 levels, while the ^{137}Cs levels were a little lower.

Grain products contributed 43% and milk products 36% to the total ^{90}Sr intake, and 23% of the ^{137}Cs in the diet came from meat, 41% from grain products, and 17% from milk products.

The ^{90}Sr as well as the ^{137}Cs diet levels were on the average significantly higher in Jutland than in eastern Denmark.

9.4. Strontium-90 and Caesium-137 in Humans

The ^{90}Sr mean content in human bone (vertebrae) collected in 1972 was 1.9 S.U. in new-born children, 2.5 S.U. in infants, 1.8 S.U. in children and teen-agers, 1.7 S.U. in adults (20-29 years old), and 1.4 S.U. in adults of more than 29 years. The 1972 bone levels were apart from new-born lower than the 1971 levels.

The mean content of ^{137}Cs in the human body in 1972 was estimated from whole-body countings to be 2.2 nCi (16 pCi ^{137}Cs/g K), a little higher than the 1971 level.

9.5. Strontium-90 in Sea Water

The mean content of ^{90}Sr in inner Danish waters was approx. 0.6 pCi ^{90}Sr/l in 1972, i.e. unchanged from the levels in previous years. The ^{137}Cs concentration was approx. 1.2 times the ^{90}Sr concentration in surface water collected in the inner Danish waters (mean salinity 15 o/oo).

9.6. The γ-Background

The γ-background measured at the State experimental farms in 1972 was 6.0 μR/h.

9.7. Summary

The concentrations of long-lived fall-out nuclides in ground-level air and precipitation collected in 1972 were 30-40% of the levels found in 1971.

In milk produced in 1972 the ^{90}Sr and ^{137}Cs levels were 10-20% lower than the 1971 levels. In grain from 1972 the levels were 30-60% of those in 1971.

The ^{90}Sr and ^{137}Cs levels in the total diet consumed in 1972 were nearly equal to the 1968, 1969, 1970, and 1971 levels.

The ^{90}Sr concentrations in human bone were a little lower in 1972 than in 1971.

APPENDIX A

Calculated Fall-out in the Eight Zones in 1972

Zone	mm precipitation in 1972	mCi Sr-90/km² in 1972	Accumulated mCi Sr-90/km² by the end of 1972 (0-30 cm)
I: N. Jutland	647	0.47	57
II: E. Jutland			
III: W. Jutland			
IV: S. Jutland			
V: Funen			
VI: Zealand	606	0.45	48
VII: Lolland-Falster			
VIII: Bornholm	471	0.36	48
Area-weighted mean	632	0.46	55

The amounts of precipitation were obtained from ref. 9, and from 4.1 and 4.2.

APPENDIX B

Statistical information

Zone	Area in km² 15) 1971	Population in thousands 15) 1971	Annual milk production in mega-kg 14) 1971	Annual wheat production in mega-kg 13) 1970	Annual rye production in mega-kg 13) 1970	Annual potato production in mega-kg 13) 1970	Vegetable area in km² 13) 1970	Fruit area in km² 13) 1970
I: N. Jutland	6,171	457	911	110	69	897	23	17
II: E. Jutland	7,561	841	1,258					
III: W. Jutland	12,104	661	926					
IV: S. Jutland	3,929	239	572					
V: Funen	3,486	434	393					
VI: Zealand	7,435	2,146*	395	402	64	136	84	109
VII: Lolland-Falster	1,795	125	68					
VIII: Bornholm	588	47	39					
Total	43,069	4,950	4,562	512	133	1,033	107	126

*1,345,000 people were living in Greater Copenhagen and 801,000 in the remaining part of Zealand.

APPENDIX C

In 1972 the agreement between predicted and observed ^{90}Sr levels was poor. The observed values were significantly greater than the predicted ones if the models from 1970-71 shown in table C1 were used. If the models from 1968[17] were applied the gap between observations and predictions was reduced, but the observed values were still probably significantly greater than the predicted ones. As regards ^{137}Cs the agreement between observations and predictions was better than for ^{90}Sr for the 1971 models (table C2) as well as for the 1968 models[17].

We are at the moment inclined to believe that the ^{90}Sr in the soil is not made unavailable as fast as we thought in 1971[1] (i.e. with an effective half life of 4 years) or that some of the "unavailable" Sr perhaps becomes available again as the time goes by. As we expect the fall-out rate in 1973 to be even lower than the 1972 rate, we shall have the opportunity to study the soil uptake nearly undisturbed of direct contamination one more year.

Table C 1

A comparison between observed and predicted Sr-90 levels in the human food chain in Denmark in 1972

Sample and location	Observed	Predicted	Equation used for the prediction	Predicted from 1968 models [17]
Milk from Jutland	7.8	6.8	$S.U. = 1.04d_{(i)} + 0.47d_{(i-1)} + 0.26A_{by(i-1)}$	7.4
Milk from the Islands	5.0	3.8	$S.U. = 0.78d_{(i)} + 0.47d_{(i-1)} + 0.18A_{by(i-1)}$	
Rye from Jutland	93	60	$S.U. = 204d_{(j-a)} + 2.06A_{by(i-1)}$	59
Rye from the Islands	57	32	$S.U. = 156d_{(j-a)} + 1.20A_{by(i-1)}$	
Barley from Jutland	97	58	$S.U. = 161d_{(j-a)} + 2.14A_{by(i-1)}$	61
Barley from the Islands	43	28	$S.U. = 94d_{(j-a)} + 1.24A_{by(i-1)}$	
Wheat from Jutland	137	79	$S.U. = 154d_{(j-a)} + 3.14A_{by(i-1)}$	74
Wheat from the Islands	57	47	$S.U. = 136d_{(j-a)} + 2.24A_{by(i-1)}$	
Oats from Jutland	107	39	$S.U. = 70d_{(j-a)} + 1.60A_{by(i-1)}$	39
Oats from the Islands	46	20	$S.U. = 56d_{(j-a)} + 0.96A_{by(i-1)}$	
Potatoes from Jutland	2.9	2.4	$pCi\ Sr\text{-}90/kg = 0.13d_{(i)} + 0.11A_{by(i-1)}$	2.9
Potatoes from the Islands	2.9	1.1	$pCi\ Sr\text{-}90/kg = 0.18d_{(i)} + 0.062A_{by(i-1)}$	
Total diet from Jutland	9.1	7.8	$S.U. = 0.89d_{(i)} + 1.26d_{(i-1)} + 0.25A_{by(i-1)}$	8.3
Total diet from the Islands	7.2	5.4	$S.U. = 0.84d_{(i)} + 1.27d_{(i-1)} + 0.21A_{by(i-1)}$	
Newborns' bone	1.9	1.0	$S.U. = 0.164d_{\frac{i+(i-1)}{2}} + 0.017d_{(i-2)} + 0.037A_{by(i-1)}$	1.2
Adults' vertebrae	1.6	1.2	$S.U. = 0.021d_{\frac{i+(i-1)}{2}} + 0.039d_{(i-2)} + 0.056A_{by(i-1)}$	1.6

The prediction models were calculated from data collected in 1962-1970 (for grain 1962-1971)
d is the fall-out rate in mCi Sr-90/km^2 (table 4.1.1). A is the estimated, available, accumulated fall-out in mCi Sr-90/km^2 calculated for an effective half-life of Sr-90 in the soil of 4 years.
(i) is the current year, (i-1) the year before etc. (j-a) is July-August.

Table C 2

A comparison between observed and predicted Cs-137 levels in the human food chain in Denmark in 1972

Sample and location	Observed	Predicted	Equation used for the prediction	Predicted from 1968 models [17]
Milk from Jutland	8.1	5.4	$pCi\ Cs\text{-}137/g\ K = 4.45d_{(i)} + 1.47d_{(i-1)} + 0.39d_{(i-2)}$	6.7
Milk from the Islands	4.6	3.2	$pCi\ Cs\text{-}137/g\ K = 2.53d_{(i)} + 1.63d_{(i-1)}$	
Rye from Jutland	42	34	$pCi\ Cs\text{-}137/kg = 131d_{(m-a)}$	32
Rye from the Islands	31	30	$pCi\ Cs\text{-}137/kg = 118d_{(m-a)}$	
Barley from Jutland	26	24	$pCi\ Cs\text{-}137/kg = 92d_{(m-a)}$	25
Barley from the Islands	17	21	$pCi\ Cs\text{-}137/kg = 83d_{(m-a)}$	
Wheat from Jutland	23	23	$pCi\ Cs\text{-}137/kg = 89d_{(m-a)}$	22
Wheat from the Islands	15	18	$pCi\ Cs\text{-}137/kg = 71d_{(m-a)}$	
Oats from Jutland	26	21	$pCi\ Cs\text{-}137/kg = 81d_{(m-a)}$	20
Oats from the Islands	24	18	$pCi\ Cs\text{-}137/kg = 73d_{(m-a)}$	
Potatoes from Jutland	6.9	2.7	$pCi\ Cs\text{-}137/kg = 5.6d_{(i)}$	2.5
Potatoes from the Islands	2.8	2.2	$pCi\ Cs\text{-}137/kg = 5.3d_{(i)}$	
Beef	38	24	$pCi\ Cs\text{-}137/kg = 37d_{(i)} + 5.2d_{(i-1)}$	50
Pork	53	51	$pCi\ Cs\text{-}137/kg = 37d_{(i)} + 17d_{(i-1)} + 5.2d_{(i-2)}$	56
Total diet from Jutland	31	35	$pCi\ Cs\text{-}137/day = 8.8d_{(i)} + 11d_{(i-1)} + 6.1d_{(i-2)}$	30
Total diet from the Islands	29	25	$pCi\ Cs\text{-}137/day = 7.3d_{(i)} + 11.3d_{(i-1)} + 3.2d_{(i-2)}$	
Whole body from the Islands	16	18	$pCi\ Cs\text{-}137/g\ K = 4.2d_{(i)} + 4.2d_{(i-1)} + 8.6d_{(i-2)}$	39

The prediction models were for milk calculated from the data collected 1962-1970, for grain 1962-1971, for potatoes 1963-1971, for meat, total diet and whole body 1963-1970.
(m-a) is May-August and the fall-out rates are measured in mCi Sr-90/km^2
(cf. also remarks to table C 1).

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